THE BRITISH JOURNAL

OF

OPHTHALMOLOGY

JANUARY, 1939

COMMUNICATIONS

A STANDARDIZED LANTERN FOR TESTING COLOUR VISION

BY

L. C. MARTIN, D.I.C., A.R.C.S., D.Sc.

ASSISTANT-PROFESSOR IN THE TECHNICAL-OPTICS SECTION, IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

Abstract

A Lantern for testing Colour-Vision is arranged to show test colours in pairs as in the Board of Trade Lantern. It is adapted to use electric light, and is standardized by stringent testing. The paper discusses the experiments and considerations which led to the formulation of the allowable tolerances in the transmission and colour co-ordinate specifications of the filters, the colour temperature of the lamps and so on. The results of tests on normal and colour-defective subjects are described.

In the year 1912 a special Departmental Committee of the Board of Trade published a report on sight tests (including colour vision) with special reference to the requirements of the Mercantile Marine. The type of lantern for colour vision testing advocated by that report has been in constant use by the Board of Trade since that time, and a committee of the Medical Research Council, in considering colour vision tests for entry into the Royal Navy, has recently advocated the employment of a similar lantern for Naval purposes.*

* Medical Research Council, Special Report Series No. 185, p. 37 (1933)

Small coloured lights are shown by the original Board of Trade lantern, singly or in pairs. The angular diameters of the lights are fixed by circular diaphragms, and the observer views them from a fixed distance, effectively twenty feet, with the aid of a mirror. The larger apertures are intended to represent the subtense of an average ship's light at 200 yards' distance. The small apertures, when shown in pairs, represent two ships' lights separated by a beam of 25 ft. as seen at 2,000 yards. The light is furnished by an oil lamp and the colour filters consist of specimens of "flashed ruby" and "signal green" glasses combined with neutral photographic filters. In this way red, green, and neutral coloured lights can be shown, but the transmission of each set of filters is intended to give equal brightness to the normal eye. Some nine filters in all, red, green, and neutral, mounted near the circumference of a disc of approximately 11 ins. diameter are employed. The ruby and signal-green glasses vary somewhat amongst themselves, representing permissible variations in coloured glasses approved by the Board of Trade and Trinity House for ships' lights.

Conditions have greatly changed since 1912, and the general availability of electric power suggested the possibility of substituting an electric light for the oil lamp and thus improving the simplicity and convenience of the lantern. At the request of the Colour Vision Sub-Committee of the Medical Research Council, the present writer undertook to design such a lantern, aiming at the simplification of the whole test as far as possible consistent with efficiency.* Many refinements and details of the construction have been worked out by Messrs. Kelvin, Bottomley, and Baird, Ltd., who undertook the manufacture.

The general construction is shown in the figure (Fig. 1). The colour filters are mounted around the circumference of a cylindrical drum rotating about a vertical axis. The movement is effected by a small hand-capstan-wheel in the base of the lantern. A handle close to the capstan permits the diaphragm apertures to be changed; these apertures comprise two of diameter 0·2 ins. and two of diameter 0·02 ins. The colours shown are indicated by key letters appearing in a window at the side of the lamp, the letters being mounted in suitably disposed apertures of the same drum which holds the colour filters. Nine colour pairs can be shown, and a number, corresponding to the pair exhibited, also appears at the window. An extension of the cylinder containing the apertures indicates, at the same window, the dispositions of the apertures seen by the observer. An auxiliary 15-watt lamp, with a separate switch, provides light for recording results at the rear of the lantern.

* British Patent, 449,047 of 1936.

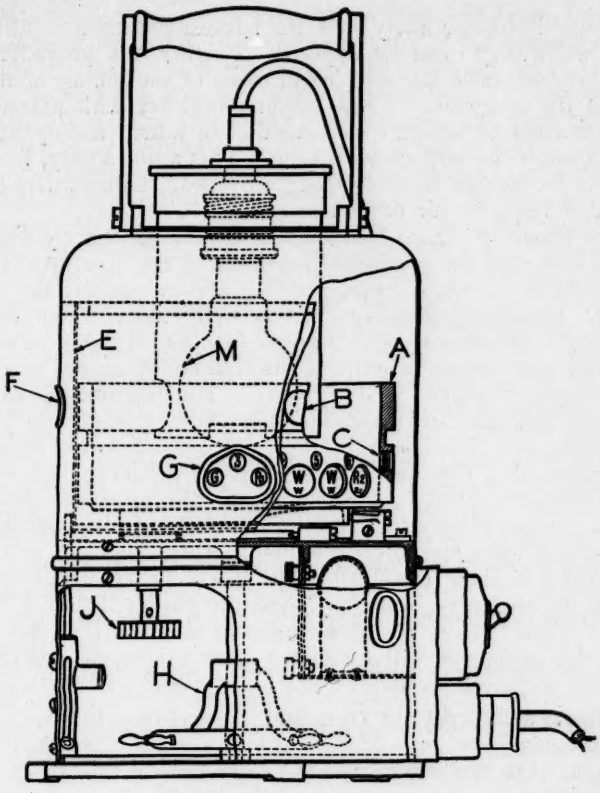


FIG. 1.*

A. Wheel carrying colour filters and indicators.
B. Colour filters.
C. Indicators.
E. Sector carrying diaphragms.
F. Front aperture or window.
G. Aperture for indicators.
H. Hand-wheel for carrying filters.
J. Head for control of stops.
M. Main lamp.

It is not the intention to make the lantern test so subtle that it will reject cases in which the colour deficiency is not of a dangerous character; this is the chief justification for the attempt to simulate practical conditions as closely as possible for use in the testing of large numbers of candidates, rather than to perfect any test, however good, of a laboratory type. Other types of lantern test have suffered from over-complexity and, bearing this in mind, it seems that even the original B.T. lantern colour filters may be drastically reduced in number. Since the least saturated " red " and " blue-green " allowed by the regulations

* Block lent by Messrs Kelvin, Bottomley and Baird.

for ships' lights are likely to be the hardest colours to distinguish from white they must be retained. Further, the provision of a relatively saturated red will detect cases of shortening of the red end of the spectrum. These colours, together with neutral, are all that need be shown; the retention of others merely leads to more complexity and waste of time. This applies only, however, to tests for marine watch-keeping purposes. Other filters can be added if required for other tests.

The Board of Trade Lantern has been criticised by some for the reason that the apparent brightness of the apertures, even if equalised to the normal eye, may not appear equal to the colour-blind. Colour-blind persons, as is well known, often describe changes of brightness as changes of hue, and it therefore appears possible that clever brightness discrimination might enable the correct colour names to be given. The luminosity curves of normal subjects and deuteranopes show comparatively little variation, but there is a marked difference between these and protanopes.* The hue wave-length of the deep red filter is approximately 0·625μ, at which region the apparent luminosity of an " equal energy spectrum " is only about one-twentieth part of the maximum spectral brightness to some classes of protanope, whereas it is about one-third of the maximum spectral brightness to the normal eye. We may therefore expect that if a " red " and " white " have the same apparent luminosity to the normal eye, this protanope will see such a great brightness contrast that he will employ it to identify red under lantern conditions.

This is admittedly the case, and it is easily noticed in examining the records of tests of some colour-blind subjects with such a lantern. On the other hand the operation of this basis of discrimination is made extremely difficult with the small apertures of the Board of Trade Lantern, where considerable brightness differences are hard to detect. A person with a deficiency of such a marked amount invariably makes glaring mistakes, especially in his confusion of green and white.

In order to minimise the risk (small though it has proved in practice) of passing a candidate with such a deficiency, the new lantern is fitted with auxiliary dimming filters which can be employed (when required) to reduce the brightness of either right or left-hand light to about one-third of its original value without altering the quality of the colour. A protanope using apparent brightness inequality to identify red will probably guess at colour differences when shown two whites or two greens of unequal brightness.

* F. H. G. PITT,—Medical Research Council. Special Report Series No. 220, p. 25 (1935).

Only a limited number of the original Board of Trade Lanterns were manufactured and, from the experience of the present writer, the aim at equality of brightness of the coloured lights as seen by the normal eye does not seem to have been very accurately realised. When the first of the new lanterns had been made up with filters very carefully prepared and tested to secure accurate brightness equality throughout, it was tested and compared with one of the original Board of Trade Lanterns. In the opinion of the writer the older lantern showed relatively great brightness contrasts and inconsistencies; if this observation was correct (and it was confirmed by another observer) it seems that the practical success of the older lanterns has not been spoilt by the technical errors in their production. It is not easy to make photographic neutral filters to exactly prescribed densities.

This does not imply that a deliberate carelessness in the production of the new lantern will ensure success or inspire confidence. Every lantern ought to give the same results for the same observer, but in view of the complexities of colour-blindness we have no means of knowing the limits of tolerance in regard to the variations of the colour-filters and source of light which would be required to ensure such a consistency. It would appear probable, however, that if the allowable variations of the filters, etc., are small in comparison with those detectable by the normal eye under the conditions of the lantern, all reasonable requirements will be fulfilled.

Discrimination of brightness and colour is difficult when the sources are separate bright points in a dark field. Even with the large sources the effect of a modifying filter reducing transmission to one third does not appear very drastic; it will be recalled that stellar magnitudes have long been divided into six " just distinguishable " steps for the range of visible stars; each step has 2·5 times the brightness of the step below it. Conditions are a good deal more favourable in the lantern owing to the close angular position of the apertures, but a 30 per cent. difference of brightness is extremely difficult to detect with certainty, unless careful observation is made with the large apertures, the observer being close up to the lantern. With the small apertures the difference is not detectable. It therefore appears reasonable to suggest that tolerances of the order of $\pm$ 15 per cent. of the standard are allowable as far as brightness is concerned. Even this accuracy cannot be attained, however, unless considerable care is taken in production.

The flame of the oil lamp employed in the original lantern would probably have a colour temperature of about 2,000°K or slightly more,* and a brightness of the order of 0·012 candles per

* J. W. T. WALSH.—Photometry, p. 478.

sq. mm. It is proposed in the new lantern to use a specially selected single-coil 40 watt opal bulb lamp (Ediswan Fullolite). Such a lamp provides a fairly uniformly illuminated " disc of light " about 2½ inches in diameter, and makes an efficient substitute for an oil lamp flame.

As a preliminary experiment, measurements were made in the laboratory of the relative brightness variation of one such lamp across a diameter of the bulb perpendicular to the axis, and from tests at equal linear intervals with an accurate surface-brightness photometer, the directions of the view being parallel, the following figures (arbitrary units) were obtained: 97·4, 102·6, 102·6, 100, 97·4, 97·4, 92·8. Provided the extreme edge of the bulb is not used, and if lamps free from noticeable irregularity in the bulb are selected, selected lamps may be expected to be adequately uniform. The same photometer was used to obtain measurements of the intrinsic brightness of the opal bulb relative to a paraffin oil-lamp flame with flat wick, and the ratio was found to be 78 : 100. Most of these lamps have, however, shadows and reflections from the filament supports on some parts of the globe; it is therefore important to select the most uniform aspect of the bulb and to place this part adjacent to the apertures in the lantern. The finally selected parts of the bulb will be suitably marked.

The lamps for the lantern will be specially selected and will be fitted with screw-cap holders to prevent the ready employment of unsuitable lamp bulbs.

Lamps of the above kind, running at 240-200 volts normally have a colour temperature, according to the makers, of between 2,500° and 2,550°K. The life is about 1,000 hours and the change of colour temperature during life is about 1·8 per cent. This change has only a small effect on the luminosity transmission of the colour filters. Mr. J. G. Holmes of Messrs. Chance Bros. & Co., Ltd., kindly sent me the following figures for typical deep-red and signal-green glasses:

	Percentage Transmission of Visible Light		
	2360°K	2500 K	2848°K
Red - -	9·6	9·0	7·9
Blue-Green -	8·8	9·3	10·3

From these figures it can be seen that the change in relative transmission of the red during the life of the lamp will be approximately from 8·75 per cent. to 9 per cent., while the transmission of the green will fall from about 9·5 per cent. to 9·3 per

cent. Changes of this order will be negligible under lantern conditions, but it will be advisable that a record shall be kept of the time of burning for every lantern so that the bulb may be changed after 1,000 hours' use.

The average surface brightness of 40 watt lamps varies slightly in lamps for different voltages. Assuming the rated surface brightness of a 230 volt lamp to be 100, a 250 volt lamp has a brightness of about 97 and a 200 volt gives about 105. Variations of this kind from lantern to lantern would not be of material importance, but will be avoided as explained below.

According to the makers, a change of ± 4 per cent. in voltage will give approximately a change of ± 15 per cent. in brightness and ± 2 per cent. in colour temperature; thus a 240 volt lamp running on 230 v. will be near a colour temperature 2,500°K instead of 2,550°K.

The case of low-voltage supply, 100-130 volts, requires separate consideration, but there are now comparatively few places where this kind of voltage is in use. The makers state that the range of colour temperature for 100-130 volt lamps is 2,700°K to 2,650°K, the lower voltage lamps running at the higher colour temperature. These lamps also have a higher surface brightness. Taking a 230 volt 40 watt lamp as 100, the surface brightness of 40 watt lamps ranges from 133 for a commercial 100 volt lamp to 126 for a 130 volt lamp. Lamps of this kind can be suitably under-run in the lantern, and special provision must clearly be made for this.

The rapid extension of the grid system has resulted in some relaxation of the Board of Trade regulations regarding the necessary precision of voltage on public supply circuits, and it is understood that variations of ± 6 per cent. may be encountered; as this would mean a possible brightness variation of more than ± 20 per cent., it appears that such fluctuations might cause appreciable variations in the performance of the lantern. The difficulties noted in this and the previous paragraph are clearly best met by the provision of a suitable rheostat and voltmeter with each lantern. The lamps will then be run at the pre-determined voltage to give a standard surface brightness, and such lamps will be selected in respect of a certain tolerance in colour temperature as described below.

Selection of Colour-filters and Neutral Filters

Messrs. Chance Bros. & Co., Ltd., were good enough to provide the writer with specimens of ruby and signal-green glass representing the extreme variations allowable in glasses for ships' lights. The darkest and lightest red and the lightest blue-green

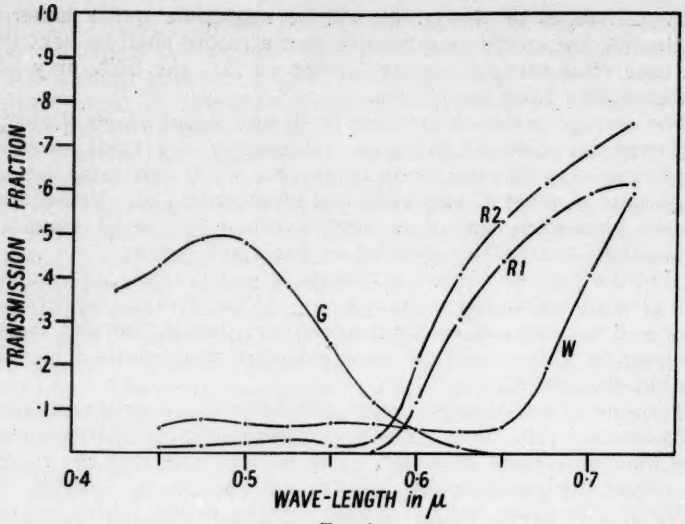


FIG. 2.

were selected for use in the first experimental lamp. The curves for spectral transmission are given in Fig. 2. The percentage luminosity transmission for a source of colour temperature 2,600°K are:

Red 1 = 8·8 per cent.
Red 2 = 13·2 „
Green = 16·2 „

} As calculated from the spectrophotometric transmission measurements.

These are not the actual standards finally adopted in the commercial lantern, but are very close approximations to them.

Measurements of the density of the photographic neutral filters fitted to an original Board of Trade Lantern allowed of the specification of a series of neutral filters which, when employed with the opal-bulb lamp, should produce the same effect as the original lantern with its oil lamp. After some preliminary trials with photographic filters, a set of Ilford Neutral Filters was obtained which gave an effect approximating very closely to the Board of Trade Lantern now actually in use at the Board of Trade. These filters were produced to yield exactly prescribed densities.

A routine method of producing photographic filters to prescribed densities with a minimum of uncertainty has now been worked out in conjunction with the makers of the new lantern, Messrs. Kelvin, Bottomley, & Baird, Ltd., and a photometric comparator is used to ensure that the photographic filters will yield the required effect, under the lantern conditions. Considerable care

is essential in tests of this kind, as the scattering of the light by a photographic filter makes its apparent density dependent largely on the conditions of operation. The total apparent density of colour filter *plus* neutral is a little over 2.

Photographic filters are selected for use in the new lantern mainly because the experience of their use in the old Board of Trade lantern has demonstrated their stability under lantern conditions. Filters containing a dye might be expected to deteriorate if allowed to become warm. It is an advantage also that the grain of the filter helps to make the brightness of the aperture less dependent on any slight local irregularity in the luminosity of the opal bulb.

The " neutral " filters first selected consisted of a piece of neutral glass with a photographic filter. A combination of another neutral with an Ilford filter proved too yellow, whereas two photographic neutral filters gave an effect with the opal lamp rather more white than the oil lamp with photographic filter only, and made the test easier to colour defectives. A return was therefore made to the original neutral glass *plus* photographic filter which had proved satisfactory under trial. Most of the tests with the experimental lamp were made with photographic filters only for " white." This was the case in the very first set of trials* with an original B.T. lantern fitted with an opal-bulb lamp carried out by Surgeon Commander Macleod and the present writer in 1931. The use of the neutral glass will make the white a little harder to distinguish from the red.

Tolerances.—The actual standards for the filters to be employed will be a set of glass filters (together with the corresponding photographic neutrals) which measurements have shown to represent a close approximation to the mean for the available glasses having the required colour quality.

The question of the practical tolerances for variations amongst the colour filters, apart from the compensating filters, is not an easy one to settle. As stated above, we have no data for determining how far individual lanterns may vary before they give different results with colour-defective eyes, and the only common-sense method is therefore to prescribe the closest limits which can reasonably be expected in commercial production.

Through the kind co-operation of Messrs. Chance Bros. & Co., Ltd., a supply of glass has been obtained for all four sets of filters: R1, R2, G and W, and the greatest care has been taken to make sure that the glasses finally selected were as closely as possible identical in colour. The reds could be selected from flashed glasses, but the greens and neutrals have had to be ground and polished to the required thickness.

* Medical Research Council.—Special Report Series, *ibid.*, p. 1.

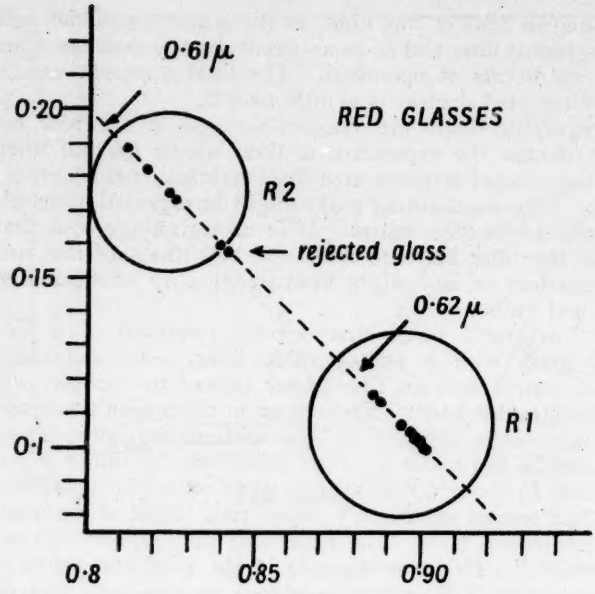


FIG. 3a.

Colour co-ordinates of glass colour-filter, in Wright's system. Abscissae are R values, ordinates are G values.

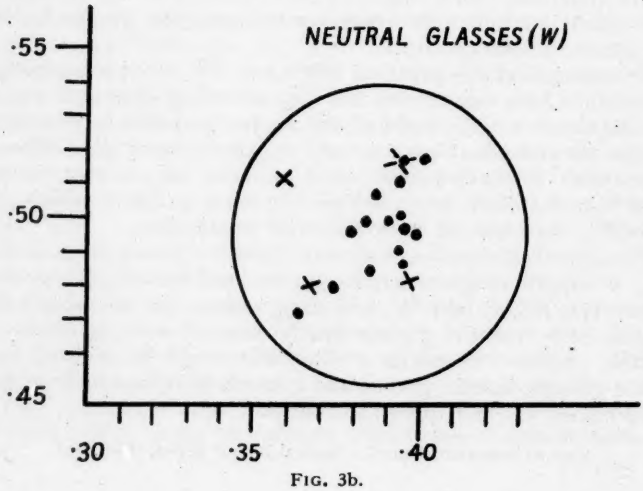


FIG. 3b.

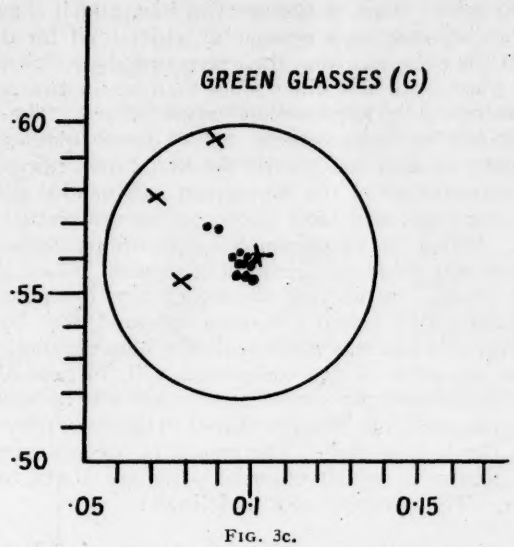


FIG. 3c.

The tolerance for colour quality must be as strict as possible consistent with the avoidance of undue difficulty in obtaining the quantity of glass required for the commercial production of the lantern. The trichromatic coefficients of a representative set of nine R1, eight R2, thirteen G, and fifteen neutral glasses were measured, using a source of colour temperature 2,848°K. The points so determined are plotted in Figs. 3a, 3b, and 3c, in which the Wright system* of units is employed. Some points for rejected glasses are omitted. In order to obtain results which would approximate to those given by an "average observer," the quantity scales for R, G, and B, for the actual observer were adjusted so that they gave the "average observer's" result for a measurement on the standard source, as previously determined in the colour-vision laboratory in the Imperial College.

The results have now to be related to the limits of detectable colour change. In the red region it is well known† that the limit of colour discrimination (hue-wave-length change) under the conditions of the colorimeter corresponds near 0·61μ to ·0011μ, and near 0·62μ to ·0015μ. The colours of the glasses fall very close to the line of spectral colours, and the range for colour discrimination can easily be shown. The circles of Fig. 3 have

* *Trans. Opt. Soc.*, Vol. XXX, p. 141, 1928-29.

† *Proc. Phys. Soc.*, Vol. XLVI, p. 459, 1934.

radii of two colour steps in the spectral line, and it thus appears that this can be taken as a reasonably strict limit for the colour variation of the reds, *i.e.*, that the green or red coefficient for any R1 or R2 glass shall not differ more than about two such steps from the standard or approximate mean value. The blue coefficient should be inappreciable. The actual glasses selected easily conform to such conditions; the limits are indicated.

A representative set of the blue-green and neutral glasses has also been examined, and their colour points are plotted in Figs. 3b and 3c. When the measurements were completed, an attempt was made to determine the limits of detectable colour change in the colour triangle by varying the match first by increasing the amount of red until a colour difference appeared, then by decreasing it. A similar test was made with the blue varying.

Since an alteration of one component will, in general cause a luminosity difference, the size of such steps will be smaller than those which involve hue changes alone. However, they will give a guide in the present case. The results of the test give in each case four points, of which opposite pairs are about two colour steps apart. They proved to be as follows:

Co-ordinates of Colours Showing Limits of Detectable Colour Change.

			BLUE-GREEN.			
Blue	-	-	·388	·315	·338	·350
Green	-	-	·533	·596	·560	·578
Red	-	-	·079	·089	·102	·072
			NEUTRAL.			
Blue	-	-	·153	·091	·122	·130
Green	-	-	·480	·561	·482	·512
Red	-	-	·367	·393	·396	·538

They are plotted in the figures (crosses) and suffice to give an idea of the amplitude of the steps in these regions of the colour triangle. The circles drawn around the centres of gravity of the points representing the glasses will be seen to have radii of about two colour steps (*i.e.*, steps estimated under colorimeter conditions). The selected glasses fall easily within such limits, and it seems as in the case of the reds, that two colour steps can be taken as a guide to a reasonably strict limitation for the lantern glasses.

The diagrams in Fig. 3 show the points plotted in the W.D.W. system of units.* They can be transferred to the C.I.E. system† by the following transformation:

* W. D. WRIGHT.—*Ibid*, p. 11.

† SMITH and GUILD.—*Trans. Opt. Soc.*, Vol. XXXIII, p. 73, 1931-1932.

$$bR = 1{\cdot}3140\ X + 0{\cdot}4961\ Y$$
$$bG = 0{\cdot}1547\ X + 0{\cdot}8059\ Y + 0{\cdot}0394\ Z$$
$$bB = 0{\cdot}1862\ X + 0{\cdot}0384\ Y + 1{\cdot}0686\ Z$$

This will allow of the transformation to any other system of units in which the relations to one or other of the above systems are known. The mean co-ordinates in the C.I.E. system are as follows:

	X	Y	Z
R1	·6908	·3068	·0024
R2	·6653	·3305	·0042
G	·2348	·4345	·3307
W	·4511	·4432	·1057

The co-ordinates and the corresponding approximate limits are shown plotted in Fig. 4 for the neutral glasses.

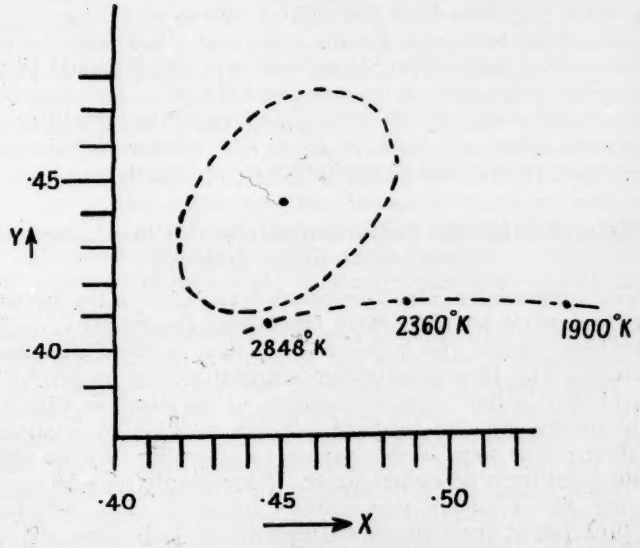


FIG. 4.

The tolerances for the luminosity transmission of the coloured glasses need not be stated separately, as the final test will be made on the combination of glass plus neutral filter. It may be noted, however, that the mean of the transmission and the maximum deviations from the mean for the glasses selected, as calculated

from colorimeter measurements with a source at 2,848K were as follows:

	Mean percentage transmission.	Maximum deviation from mean.
R1	9·28	0·80
R2	14·81	1·09
G	19·0	1·0
W	8·2	0·6

The variation of the total transmission of the glasses can to some extent be adjusted by the selection of the accompanying neutral filters. Measurements on representative sets showed that the variation of transmission can without difficulty be kept within one-tenth of the total transmission factor. This is the normal accuracy to be aimed at, but ± 15 per cent. may be suggested as a limit for the tolerance of error in the combination.

A less stringent tolerance, say, ± 25 per cent., may be suggested for the photographic neutral filters used for the auxiliary dimmers. Standards for these have also been selected.

The official tolerances for the combined filters both for colour quality and transmission, as agreed with the National Physical Laboratory after tests on ten completed lanterns agree closely with the general suggestions above, although the specification is expressed differently, and the limits adopted for variation of the colour co-ordinates are somewhat more stringent.

Tolerance for the Colour-temperature of the Lamps and Method of Initial Selection

The tolerance for colour temperature variation in the lamps used for the lantern should clearly not exceed the colour variation of the filters. First, the colour co-ordinates, in the C.I.E. system, corresponding to various colour temperatures are known.* They are plotted in the "neutral" section of the diagram Fig. 4, and it is noticed that the range of 2,360°K to 2,848°K is about two to three colour steps in that region, as determined by the approximate experiment described above. Accordingly we take one-third of the above colour temperature difference, *i.e.*, 488/3=163° (approx.) as an approximate estimate of one such colour step under colorimeter conditions; this is, then, 6·5 per cent. at 2,500°K approximately.

Referring to the makers' figures cited above, we may take it that a change in voltage of ± 6 per cent. will not cause a change in colour temperature exceeding ± 4 per cent.; and hence at a

* D. B. JUDD.—*Jour. Opt. Soc. Amer.*, Vol. XXIII, p. 366, 1933.

colour temperature of 2,500°K this ± 6 per cent. voltage change will not produce a change in colour temperature corresponding to as much as one colour step under colorimeter conditions; far less than one colour step under the conditions of the lantern.

It should be noticed, however, in passing, that even the "colorimeter conditions" of a 2° angular field are not particularly sensitive for colour discrimination. When a larger field is employed with suitable precautions the discriminable steps may be much smaller.*

Under the present conditions therefore it seems that lamps should be selected initially to give a certain brightness when run at a prescribed voltage, about 10 per cent. less than that of the supply, and this voltage should be maintained during the use of the lamp by a suitable rheostat and voltmeter. The colour temperature of the lamp can then be subject to a final tolerance to be determined.

A batch of ten lamps, initially selected with the aid of a spherical integrator, has been submitted to the National Physical Laboratory. Tests of the surface brightness of each bulb were made for a series of points around the diameter; it was then found possible to find pairs of points about 1 inch apart, on any bulb, which gave equal surface brightness, and would thus furnish equal illumination to the apertures in the lantern when the bulb is suitably positioned. By varying the voltage on each bulb the local surface brightness could be adjusted to agree with the mean brightness of the whole set; the colour temperature was then determined. It was found that the colour temperatures agreed with one another within ± 50°K, and this figure was adopted as the appropriate tolerance; it clearly represents a very small colour difference.

The rheostat and voltmeter forms a separate unit to be plugged into the lantern, and the dial of the voltmeter is illuminated so that the voltage across the lamp can be adjusted when the apparatus is being used in a darkened room. On account of the fairly wide tolerances described above there will be no occasion to try and correct small voltage variations of one or two per cent., but larger deviations can be detected. As is well known, the variation is generally greatest at certain times of the day such as dusk, when the load on the supply stations is changing rapidly, and it will clearly be better to use the lantern at times when a steadier voltage can be expected.

Tolerances for size of apertures.—It is not a particularly easy matter to produce small holes of diameter 0·02 inch with a high degree of consistency, but the N.P.L. tests of the effective areas

* D. B. JUDD.—*Ibid.*, Vol. XXVI, p. 421, 1936.

of the apertures in the first ten lanterns showed that the errors did not exceed ± 5 per cent. of the mean. This figure is taken as a tolerance for the areas; an error of this magnitude is clearly harmless in view of the allowable variations of brightness.

Considerable care is necessary that the apertures do not become choked with dust during the use of the lantern over any long period.

Method of use.—The technique of the Board of Trade Lantern has been fully described in the Report referred to above, but the arrangements of the new lantern require some modification of the directions.

In the first place, the lamp has to be mounted in the lantern so that the calibrated and marked region of the surface is turned towards the apertures. This is accomplished by a small sighting device furnished as an auxiliary to each lantern. If for any reason the lamp is subsequently removed from the lantern, it is obvious that it must be replaced exactly in the same position, and the top of the lamp holder is specially designed to facilitate this.

With regard to the actual system of tests, there are now only nine colour permutations which can be presented with the filters as fixed in the drum, and these might possibly be learned in order. Two packs of nine cards, each bearing the numbers 1-9 are therefore provided with the lantern, and these are shuffled in order to give an arbitrary order in which to exhibit the colour pairs to the candidate. It will be remembered that the colour pair exhibited is indicated by a key number appearing at the side window.

For most candidates twelve permutations will be sufficient. Take all the cards of the first pack (red) and three at random from the second pack (green). Shuffle these together and expose the combinations in the order so obtained. This will ensure that no candidate shall receive any assistance by knowing that repetition of a permutation is not to be expected.

After a few trials with one or two of the large apertures to give the candidate confidence, tests are made with both small apertures equally bright, using the order given by the cards. If the candidate's answers are perfect throughout, there is little likelihood of any defect in his colour vision. If, however, there is any ground for suspecting some defect given by uncertainty of answers (some tendency to confuse green and white, for example), the test with the auxiliary dimming filters will make his defect (if serious) much more apparent. Further, it should clearly eliminate any candidate who might pass by means of a clever brightness discrimination.

The procedure suggested is as follows: Take the nine red cards

as before and three others at random from the green pack and shuffle. Use the modifying filter holder in the topmost position, say, for odd numbers, in the next lower position for even numbers. (The bottom gives both apertures clear.) While moving the capstan handle from one filter combination position to another in this test, the modifying filter handle can be held in the half-way position, entirely screening the lights. It is clearly important that they should not appear at all before the candidate is asked to name them.

This test with the modified brightness of the lights is a very difficult one, and even a normal-sighted person may occasionally make slight mistakes owing to colour contrast effects. The following are the results of trials by four persons with normal colour vision established by a number of tests in the laboratory; dimming of one aperture was employed.

Combination shown	F. L. B.	B. K. J.	S. A. B.	L. C. M.
G W:	**G W**	**G W**	**G W**	**G W**
G G:	**G G**	**? G**	**G G**	**G G**
R G:	**R G**	**R G**	**R G**	**R G**
W R:	**W R**	**W R**	**Orange R**	***G*** **R**
W W:	**W W**	**? W**	**W W**	**W** ***R***
R W:	**R W**	**R W**	**R W**	**R W**
R R:	**R R**	**R R**	**R R**	**R R**
G R:	**G R**	**G R**	**G R**	**G R**
W G:	**W G**	**W G**	**W G**	**W G**

The present writer's results with modifying glasses are given in the last column and show two mistakes. In the first a dimmed white (shown against a bright red) is taken for green. In the second a dimmed white shown against a brighter white is taken for a red. Two young students, F.L.B. and S.A.B., make no mistakes, but a lecturer, B.K.J., is uncertain of the dimmed colour in two cases. No person should be failed through such mistakes on the dimmed lights alone unless there is definite confusion of red and green. *The use of the dimmed lights is only to be taken as helpful in deciding doubtful cases.*

Results with Partially Colour-blind and other Subjects

The procedure recommended above with cards, etc., was adopted in testing all the following cases, with the exception that only nine combinations were shown to each subject, first normally and

then modified. For convenience in presenting the results, however, the same order of the combinations and answers is used in all the tables following. The dimmed lights are shown by the small letters. All the results shown relate to the small apertures only, but in the comments following some notes will be found on the candidates' performances with the large apertures in cases where anything worthy of notice was found. The colour vision of all these persons had been previously examined by other methods.

Combination	C.H.F.B.	J.T.K.	G.V.C.D.	Y	H.L P.	B	J.C.J.
1. G W:	**G W**	**G G**	**G W**	**G W**	**G W**	**G** —	**G** *G*
2. G G:	*W W*	**G** *W*	— —	**G G**	**G** *W*	**G** *R*	*W* **G**
3. R_1 G:	**R** *W*	**R G**	**R G**	**R G**	*W R*	**R** *R*	**R G**
4. W R_1:	*R W*	*G* **R**	**W** *W*	**W R**	*G* **R**	*R* **R**	**W R**
5. W W:	**W W**	*G* **W**	*R* **W**	**W W**	*G R*	*G* **W**	**W W**
6. R_2 W:	**R** *G*	**R** *G*	**R W**	**R W**	*W G*	**R** *R*	**R** *G*
7. R_1 R_2:	**R** *W*	**R R**	**R R**	**R R**	*W* **R**	**R R**	**R R**
8. G R_1:	**G** *W*	**G R**	**G R**	**G R**	**G R**	**G** *W*	**G R**
9. W G:	**W** *W*	*G* **G**	**W G**	**W G**	**W** *R*	*R* **G**	*R* **G**
1. G W:	**G** *R*	— **W**	— **W**	**G W**	*W R*	— *G*	**G W**
2. G G:	*W* **G**	**G** —	— **G**	*W* **G**	**G** *R*	— —	**G** *W*
3. R G:	*G W*	— **G**	**R G**	**R** —	**R** *W*	— —	**R G**
4. W R:	**W** *G*	*G G*	**W R**	**W** *G*	**W R**	*G* **R**	**W R**
5. W W:	*G R*	*G G*	— *R*	**W W**	*R* **W**	— *G*	*R* **W**
6. R W;	**R** *G*	*W* **W**	**R W**	**R W**	*W G*	**R** *G*	**R W**
7. R R:	*G* **R**	**R R**	**R** *G*	**R R**	*G W*	*G* **R**	*W* **R**
8. G R:	*W G*	— **R**	**G R**	**G R**	**G R**	*R* **R**	**G R**
9. W G:	*G* **G**	— **G**	*G W*	**W G**	*G W*	— **G**	**W G**
Mistakes with undimmed lights':	9	5	4	0	10	8	4
Mistakes with dimmed lights:	12	10	7	3	11	13	3

Notes on the above cases.—H.L.P. is the worst case and makes serious mistakes even with the large lantern aperture, such as calling two greens a white and red. He is not, however, a perfect dichromat, and needs three primaries for colour matches near the end of the spectrum.

B. is deuteranomalous and confuses white and green even with the large lantern apertures.

C.H.F.B. is very deuteranomalous. He does not make mistakes with the large apertures, but confuses red with white, and green with white with the small apertures. The use of the modifying glasses makes him confuse red and green.

G.V.C.D. is also very deuteranomalous, and confused white and green even with the large apertures of the lantern. His record with these apertures shows one answer of red where it should have been green, but this may have been due to nervousness. With the modifying glasses he is clearly guessing in many cases.

J.T.K. is somewhat deuteranomalous. He makes no mistakes with the large apertures but cannot distinguish white and green with the small ones. He confuses red and green with the modifying filters.

J.C.J. is slightly anomalous but has a good colour discrimination. He is an interesting case because he made some mistakes even with the large lantern apertures, as follows:

G W called G R, W G called W W, G G called W W. Yet even with the modifying glasses and small apertures he makes no more mistakes than people with perfect colour vision. He was very conversational and may have been nervous in the first place. Sheer nervousness may cause serious errors even in these simple tests. He has a heightened sense of colour contrast, and is extremely unlikely ever to confuse red and green.

Y. is a lady who was found to give a somewhat abnormal reading with the Nagel anomaloscope, but whose colour-vision characteristics, when tested, seemed practically normal. She gives no indication of any marked defect.

The tests so far carried out indicate that the lantern in its present form should provide a means by which little doubt should remain as regards the watch-keeping abilities of any person. No case has been found in which any person with serious colour deficiency as regards hue discrimination has been able to pass. On the other hand, the test will not fail those like Y. above who may have some colour abnormality of a harmless type.

The present writer will be glad to hear the results which others may obtain and of any difficulties experienced, since an efficient test of this kind is highly desirable from the point of view of the public interest.

It is the intention to develop modifications of the lantern for use by railways and other bodies who may require special features in the lantern, such, for example, as the addition of an orange filter, but this will be made the subject of a supplementary paper.

Acknowledgments

The production of the lantern and its standardisation within such close limits has been made possible only by the co-operation of many helpers including commercial firms. Messrs. Kelvin, Bottomley & Baird, Ltd., have naturally taken the greatest burden, but sincere thanks are also due to Messrs. Chance Bros. & Co., Ltd., and to Messrs. Edison Swan Electric Co., Ltd. I am indebted to Dr. W. D. Wright for much assistance with colorimetric measurements and preliminary tests, and also to Messrs. J. Guild and R. Donaldson of the Optics division of the National Physical Laboratory for their careful work in the present connection and many suggestions. My thanks are also due to Sir John Parsons, F.R.S., for the consistent encouragement which he has given, as Chairman of the Medical Research Council's Committee on Vision, to the effort to produce a satisfactory instrument.

VITAL STAINING OF THE RETINA:
Preliminary Clinical Note

BY

ARNOLD SORSBY

LONDON

THE use of colouration in the study of tissues goes back to at least the sixteenth century but it is owing to the development of synthetic dyes in the second half of the last century and largely to the work of Ehrlich that vital staining has become a significant procedure. It has found applications in the study of the metabolic behaviour of tissues in tracing paths of transmission of fluids and sites of deposit of cells, and it is mainly by this approach that the conception of the reticulo-endothelial system has been elaborated by Goldmann, Kiyono and Aschoff. One obvious application, the *intra vitam* staining of cells for histological purposes has on the whole proved disappointing, partly because of the difficulty in fixing sections without washing the dye out. Negative results in attempts at staining the central nervous system led Goldmann to postulate the existence of a blood-brain barrier preventing dyes from reaching nervous tissue.

The conception of the blood-brain barrier gives a theoretical basis for the clinical experience that toxins circulating in the blood stream do not kill by a paralytic action on vital centres, and that toxic substances injected intrathecally are less well tolerated than when injected intravenously. The existence of a blood-brain barrier also explains the failure of therapeutic agents, such as the arsphenamides, to influence syphilitic lesions in the central

nervous system. Were this barrier one operating as between the blood and cerebro-spinal fluid—as was suggested by the earlier work of Goldmann who found the dye he used (trypan blue) mobilised in the choroidal plexus—no great therapeutic problem would be involved, for medications could be injected intrathecally. That the barrier is much more complex is shown by the fact that dyes that penetrate the cerebro-spinal fluid do not necessarily stain the brain (Goldmann[1] and others) and that staining of the brain can be achieved by selected dyes which do not pass into the cerebro-spinal fluid (Friedemann and Elkeles,[2] 1931 and 1932).

The recent recognition that central nervous tissue can be stained implies that the barrier is not absolute. Actually staining has been obtained only with basic dyes and these are all highly toxic, and it is held by some authorities (Spatz[3] and others) that such staining is supravital, occurring only in the dying animal.

These theoretical considerations have a bearing on the problem of making the normally translucent retina visible in life by vital staining. Obviously the dyes used by Goldmann and his school —the acid dyes of which trypan blue is the outstanding example— are not applicable as they do not stain the central nervous system. Experimental work on vital staining of ocular tissues, noted in an earlier publication,[6] bore out the impracticability of these dyes for staining the fundus. The possibility of using basic dyes could only be considered if it could be shown that the staining obtained with such dyes is not a supravital phenomenon, and that basic dyes of a non-toxic and locally non-irritating character are available.

1. *Experimental observations.*—A large number of basic dyes, such as gentian violet and other blue and green dyes, were tried experimentally in rabbits. Such staining as was obtained in the fundus was so transitory as to be doubtful, and invariably with doses giving any suggestive staining the animal collapsed. Rather similar findings had been obtained by Kikai.[4] Staining of the brain as determined post-mortem was not always particularly deep, and in the course of this work the failure of the non-toxic acid dyes to stain the brain and retina was confirmed.

To overcome the inherent toxicity of the basic dyes a study was made of a number of basic dyes containing sulphonic acid radicles, as sulphonation is one of the ways in which the toxicity of substances is reduced by the body. The addition of a sulphonate radicle renders a basic dye chemically an amphoteric one —and the question remained whether this detoxicating chemical change would interfere with the properties of basic dyes to stain nervous tissues. Rhodamin dyes were also studied, as they promised to be less toxic than the pure basic dyes. As in the case with the basic dyes it was found that not all sulphonated

dyes were equally effective as staining agents, and the toxicity of the different dyes varied largely. The first satisfactory results were obtained by Light Green S.F., a sulphonated triphenylmethane dye and Fast Acid Violet, a rhodamine dye. They were not highly toxic and gave satisfactory staining of the brain in the intact animal.

The availability of non-toxic dyes that stain the nervous tissue did not, however, solve the whole problem. With these dyes whilst effective staining of the brain could be obtained in the intact animal, staining of the fundus was, as with the pure basic dyes, of the most transient character. The retinal vessels could be seen carrying a coloured blood-stream for about two minutes, but the colouration of the fundus amounted to little more than a transient flushing. As the observations of Fischer[5] and of Kikai that basic dyes are reduced to the leuco-base in the eye had been confirmed, the question arose whether the damaged retina would remain stained after injection. With this object experimental degeneration of the retina was induced by septojod and thermocautery according to the procedures described elsewhere.[6] It was found that under such conditions an intense staining of the fundus persisting for several hours was obtained, subsequent to the transient flushing seen in the normal animal and also observed in these specially prepared animals. Rabbits, both normal and with damaged retinae—the latter being stained—were demonstrated at the January, 1937, meeting of the Section of Ophthalmology of the Royal Society of Medicine.

In subsequent work experimental degeneration of the retina was obtained by the intravenous injection of 5 c.c. of 2 per cent. sodium iodate, and the dyes used were Kiton Fast Green V and Xylene Fast Green B (tetramethyldiamino-benzhydrol-naphthalene-disulphonic acid), which proved less toxic and more satisfactory as a staining agent. The allied Wool Green S. had also been found useful.

*Clinical applications.**—The clinical exploration of the possibility of vital staining of the retina had become feasible with the finding of dyes that behaved like basic dyes as far as staining of the central nervous system was concerned and were in addition non-toxic. The experimental observation that the damaged retina retained the colour suggested the possibility that the diseased retina in man might behave similarly. The dye used throughout in clinical work was Kiton Fast Green V—and after preliminary toxicity tests on monkeys the clinical dose was gradually built up. In macacus rhesus weighing 3 kilos, 15 c.c. of the 10 per cent.

* Patients with stained fundi were demonstrated at the Physiological Society in February and at the Ophthalmological Society in May, 1938.

Fundus appearances in a case of retinal detachment after intravenous injection of 20 c.c. of Kiton Fast Green V, 10 per cent. solution.

Note the stained atrophic disc, two atrophic patches and the atrophic edge of the disinsertion.

solution intravenously is non-toxic, in man an intravenous dose higher than 40 c.c. has not been used, and judging by animal experiments a higher dose is necessary to obtain the best results for staining of the retina.

At this stage it is not feasible to indicate the full clinical possibilities of vital staining of the retina. The method of use thus far evolved and a few observations are all that can be given.

(*a*) *Method of administration.*—A 10 per cent. solution of Kiton Fast Green is prepared by dissolving the dye at 60°C., filtering twice at 35°C., and sterilising by Tyndalisation. Twenty to thirty c.c. of this solution, warmed to body heat, are injected intravenously. After the first three to four c.c. the patient assumes a faint greenish colour, which deepens as more dye is injected. At the end of the injection the patient is deeply green, the face being greener than the rest of the body. The colour deepens during the first half hour, and begins to fade after three to four hours; generally it disappears for all practical purposes within eight to ten hours. The dye is excreted mainly through the kidneys and the urine remains coloured for two to three days.

In giving the injection attention has to be paid to several points. Owing to the dark colour of the solution special care has to be exercised in excluding air bubbles. It is also desirable to give the injection very slowly, otherwise patients are apt to vomit. Should vomiting occur the needle can be left in situ and the injection continued after a short while.

At the present, biologically standardised preparations of the dye are not yet available, so that it is necessary to test each sample of dye for toxicity.

(*b*) *Clinical observations.*—As the dye is not selective for the retina, lesions other than retinal are shown up. The blood vessels themselves do not stain, but exudates, whether choroidal or retinal, take up the dye avidly. In this, there is no advantage to be gained by using the dye, as these changes are visible ophthalmoscopically. With the doses used so far the retina in optic atrophy does not stain; in several cases all that has been observed has been a toning down of the normal red reflex. The atrophic disc itself does, however, stain green, and a suggestive finding has been obtained in one case in which vision in one eye was 6/60 and ophthalmoscopically the fundus appearances were normal; on injection, the normal eye gave no staining, the eye with defective vision gave distinctly green colouration of the disc. (In this case a dose of 40 c.c. was given.) Suggestive results have also been obtained in detached retina. In one case, the detachment, whilst not becoming green with a 30 c.c. injection, lost its normal colour, and in the subdued background a series of tears which were previously not visible, were clearly seen as

red holes. In another case—illustrated in the colour plate—a large disinsertion which had not been observed in an exhaustive ophthalmoscopic exploration, became visible after injection of the dye (20 c.c.) the edge of the retina at the disinsertion becoming distinctly green and standing out in marked contrast to the red area uncovered by the disinsertion.

In view of the fact that normal retina decolourises all the dye that reaches it, and that colouration seems to depend upon the degree of inefficiency of the retina, it is obvious that equally deep staining is not to be expected in cases showing unequal degrees of retinal damage. Furthermore, as the dose necessary for staining experimentally damaged retina in rabbits (5-8 c.c.) suggests that higher doses than those so far employed clinically will have to be used, these preliminary clinical observations are offered as showing not the scope of vital staining of the retina, but the fact that the procedure is feasible.

My thanks are due to my collaborators in the preliminary experimental work, especially to Dr. A. Elkeles; and to the London County Council for facilities for the work. I am obliged for help in the clinical work to Dr. R. M. Stewart, Dr. E. C. Dax, Dr. H. Baker and my house surgeons at the Royal Eye Hospital, Miss E. Kennedy and Mr. J. Day. To the firms of Crookes' Laboratories, Clayton Aniline Co., Ciba, Imperial Chemical Industries, Sandoz and Etablisement Kuhlmann, I am obliged for their courtesy and helpfulness in supplying samples of dyestuffs, and to the *Brit. Jl. of Ophthal.* for a grant towards the expenses of this investigation.

REFERENCES

1. GOLDMANN, E.—*Abhandl. Preuss. Akad. Wissensch.*, p. 1, 1913.
2. FRIEDEMANN, A. U. and ELKELES, A.—*Deutsch. Med. Wochenschr.*, p. 194, 1931; *Klin. Wochenschr.*, p. 2026, 1932.
3. SPATZ, H.—*Arch. f. Psychiat. und Nervenkrankh.*, Vol. CI, p. 267, 1934.
4. KIKAI, K.—*Arch. f. Augenheilk.*, Vol. CIII, p. 541, 1930.
5. FISCHER, F. P.—*Arch. f. Augenheilk.*, Vols. C and CI, p. 480, p. 1929.
6. SORSBY, A., ELKELES, A., GOODHART, G. W. and MORRIS, I. B.—*Proc. Roy. Soc. Med.*, Vol. XXX, p. 1271, 1937.

STUDIES ON THE BACTERIOLOGY OF HYPOPYON ULCER

I.—The Conjunctival Flora of Healthy Coal Mine-workers

BY

*A. J. RHODES, M.B., M.R.C.P.E.

FROM THE BACTERIOLOGICAL DEPARTMENT, UNIVERSITY OF EDINBURGH

Introduction

THE work recorded in this paper is the first of a series of investigations carried out under the auspices of the W. H. Ross Foundation for the Study of Prevention of Blindness. The work was initiated owing to the fact that over half the cases of hypopyon ulcer attending the Eye department of the Royal Infirmary of Edinburgh occur in mine-workers (coal or shale), which appears to be an unduly high percentage. The economic importance of hypopyon ulcers in miners is considerable. In severe cases the eye may be lost, and in all cases a scar remains, seriously interfering with vision, and thus the earning capabilities of the worker.

Although certain ulcers may be purely traumatic in origin, it is generally agreed that the vast majority of cases are infective. Accordingly it was felt that a suitable line of research would be bacteriological. As a preliminary to a bacteriological study of established cases of hypopyon ulcer it was considered advisable to undertake a field study of the conjunctival flora of a large number of healthy mine-workers. In this paper the bacteriological examination of some 658 coal mine-workers will be reported. A parallel study of shale mine-workers will be reported in a separate communication.

Numerous workers have, of course, studied the conjunctival flora (see Duke-Elder, 1938), both in health and disease, and its nature is very well known. I have not been able to find records, however, of any study quite comparable to this, dealing with a specialised class of worker comparatively subject to corneal ulceration and infection.

Methods

Preparation of cultures.—Men were examined at the pit-head, usually coming off their shift. On one or two isolated occasions surface-men had to be examined during the shift, but no examina-

* Working under the auspices of the W. H. Ross Foundation for the Study of Prevention of Blindness, Edinburgh.

tions were made before men began work. Cultures were taken from the conjunctival sacs before the men washed, thus obviating any watering due to soap suds.

Cultures were taken from both right and left conjuctival sacs by pulling down the lower lid and drawing a platinum loop from the caruncle laterally. The loop was immediately rubbed over the surface of a blood agar slope contained in a small round screw-topped bottle (see Mackie and McCartney, 1938). These bottles can be strongly recommended for field work of this type, their advantages over cotton-wool stoppered test tubes being as follows: they can be stored for some time without risk of the medium becoming desiccated; contamination with aerial organisms is virtually unknown; they will stand upright on a table and do not need to be supported in racks or boxes; they are very strong and seldom break even if dropped on a stone floor; the screw top is easily detached and flaming of the neck is not really necessary; the layer of medium is comparatively thin and if the bottle is held up to a strong light any colonies showing haemolysis are readily detected; the surface is broad enough to make it possible to secure isolated colonies; in many cases further plating is unnecessary, suspicious colonies being picked and subcultured directly. Blood agar in screw topped bottles forms the ideal medium for these reasons, as well as for ease of manipulation in a rather crowded space. The men, naturally, do not wish to be detained for long, and in actual practice each complete examination does not occupy more than 30-45 seconds.

On return to the laboratory the blood agar cultures were incubated at 37° C. for 48 hours and then examined. With experience it was frequently possible to determine the organisms present by naked-eye examination only, sometimes films were stained, and sometimes subcultures were prepared for further tests.

Classes of workers examined.—(*a*) At each pit approximately 40 surface workers were examined. These men perform the most varied tasks, some are labourers, bricklayers, masons, or blacksmiths. Others are engineers, electricians, and winding-men. Others again are employed on the picking-tables sorting the coal, while others push hutches (small trucks) of coal away from the cage. None of these men works below ground.

(*b*) Below-ground workers fall into three classes, oncost-worker, miner, and brusher. Oncost-workers are employed in the transport of the coal. Some work near the coal face, others at the pit bottom. These workers spend most of their time pushing hutches, they never hew coal and are thus not liable to receive flying spicules in the eye. (*c*) The term " miner " technically refers to the man who " gets " the coal away from the face. In three of the four collieries visited the coal is actually removed from

the face by a mechanical coal cutting machine. The miner in these pits is known as a "stripper" and has to use a pick to break up the coal dislodged by the cutter. In the fourth pit all the work is done by pick, the miner here being called a "hewer." Miners are, of course, very liable to receive a flying splinter of coal in the eye. (*d*) The brusher is also known as a stone-miner. He is not primarily concerned with coal at all but trims up the rock exposed by the miner. These workers are liable to receive small fragments of stone or coal in the eye. Miners and brushers constitute the main number of those injured in the eye in any one pit, and correspondingly the majority of cases of hypopyon ulcer.

Mines visited.—Examinations were carried out at mine A (189 men), W (149 men), V (160 men) and mine L (160 men), all in the Lothians area of central Scotland. The coal at mines A and V was "soft," and "hard" at W and L. Mines A and V were situated comparatively close to each other, as were W and L. The managements were, however, quite separate and employees did not mix, at any rate during working-hours. Mine A was examined in the late summer and early autumn, mine W in the winter, and mines V and L in the spring.

TABLE I

Examination of 40 Healthy Students, showing percentage of persons harbouring various organisms.

ORGANISMS GROWING IN PROFUSE OR MODERATE AMOUNT.			
	Staphylococcus albus	40	
	Diphtheroid bacilli	25	
ORGANISMS GROWING IN ANY AMOUNT.			
	Staphylococcus citreus	2·5	
	Staphylococcus chromogenicus	—	
α cocci	*Streptococcus viridans*	2·5	2·5
α cocci	*Pneumococcus* (group 4)	—	2·5
α cocci	*Pneumococcus* (type 1, 2 or 3)	—	2·5
	Diplo-bacillus of Morax	—	
	Micrococcus catarrhalis	—	
	Haemophilic bacilli	—	
	Anthracoid bacilli	2·5	
	B. coli	—	

Controls.—A control series was afforded by the examination, in October and November, of 40 healthy students. The results in Table I show that apart from the usual staphylococci, diphtheroids and harmless anthracoids, *streptococcus viridans* was the only potential pathogen found. This organism was only found in one case. The results of this examination are altogether of a different order from those to follow. It is expected that further studies in this series will deal with other groups of workmen.

Results

At the outset of the investigation it was thought that it might be possible to compare one mine with another and link up any differences in flora with some varying working condition. This is, however, manifestly impossible. A short experience of mining makes it obvious that no two mines have exactly similar working conditions. Although the coal may be roughly of the same type there are countless variant seams and faults which make minor differences. Again, the conditions of dust, moisture, ventilation and warmth vary from pit to pit. Moreover, the various pits furnished results which are of the same order, although there are, of course, minor variations here and there.

It is felt that the scope of the investigation has been large enough to furnish a reliable index of the conjunctival flora of coal-miners. A wide variety of organisms, commensals and pathogens were isolated and these will be discussed *seriatim*. Following that, the findings in the individual mines will be tabulated and referred to briefly.

Organisms isolated.—Organisms are recorded as occurring in such and such a percentage of patients, without reference to whether they were isolated from one or both eyes.

The smallest unit in each case consisted of the class of worker; thus the findings in the miners, brushers, oncost-workers, and surface-workers of each pit are recorded (see Tables III, IV, V, VI). In certain cases the percentage of various organisms in the whole pit is noted; while for certain organisms the percentage present in the whole 658 men is recorded.

Staphylococcus albus.—At the outset it was realised that this organism was present in some quantity in almost every eye. The presence of the organism has therefore only been considered worthy of record if the growth was profuse or moderate in amount. With this standard in mind the organism was found to occur in from 18 per cent. to 60 per cent. of cases, but the commonest figure was between 30 per cent. and 40 per cent. The organisms

may be regarded as harmless commensals and their presence as probably of little significance.

Diphtheroid bacilli.—These organisms also were widely prevalent and are recorded only if present in profuse or moderate amount. Figures varied from 11·6 per cent. to 56 per cent., but more usually from 30 per cent. to 50 per cent. Morphologically, these organisms were usually club-shaped, although bacillary forms were always present. The colonies sometimes showed a narrow zone of haemolysis. Diphtheroids were not tested for any further properties. The presence of diphtheroid bacilli is probably of little significance.

The following organisms occurred less commonly, and their presence in any quantity is recorded.

Pigmented staphylococci.—*Staphylococcus citreus* was sometimes present, and figures varied from complete absence up to 20·8 per cent., but few groups had a percentage higher than 10-15. A few strains of *staphylococcus chromogenicus* were isolated. These organisms resembled *staphylococcus aureus* but differed in the following tests: they were not haemolytic; they did not liquefy gelatin, or ferment mannite. These pigmented staphylococci are generally regarded as harmless commensals.

Green producing or α cocci.—Cocci producing α haemolysis were quite frequently encountered. The accompanying table (2) shows that from 17·42 per cent. to 21·2 per cent. of persons in the different mines harboured these organisms, with an average of 19·35 per cent. Various tests were carried out to distinguish between *streptococcus viridans* and *pneumococcus*. In the first place morphology was of little value. The commonest appearance was of chains of short to moderate length composed of oval cocci. Occasionally certain strains had a more definitely pneumococcal appearance. Usually, however, it was not possible to tell from morphology whether subsequent tests would prove the organism to be *streptococcus viridans* or *pneumococcus*.

Colonial appearances were not very helpful either. Sometimes typical pneumococcal colonies were encountered but more usually the colony was rough and rather granular, and it was impossible to say definitely whether the organism was streptococcal or pneumococcal. All α cocci were grown on boiled blood and a green colour watched for, to exclude the presence of a β haemolytic coccus. It is thus evident that reliance had to be placed on tests other than morphology and colonial appearances. Thus the bile test was carried out by adding one part of bile or sodium taurocholate solution to 5-10 parts of broth culture. Inulin fermentation was carried out using Hiss's serum water. In the case of organisms suspected to be pneumococcal a considerable quantity

of culture was injected intraperitoneally into a mouse, and typing carried out.

Streptococcus viridans.—An α coccus which was not bile-soluble and did not ferment inulin was labelled *streptococcus viridans*. Such organisms occurred in 11·25 per cent. of all persons examined.

Pneumococcus.—In all, strains of *pneumococcus* were isolated from 54 persons (8·1 per cent. of total); 43 of these strains presented the typical reactions of bile solubility and inulin fermentation. Eight strains fermented inulin but were bile insoluble. These were regarded as rough pneumococci. Three strains were bile soluble but did not ferment inulin. As quite a number of pneumococcal strains have been shown not to attack inulin no hesitation was felt in labelling these accordingly. The interesting observation was made that whereas the classical bile soluble and inulin fermenting strains were distributed over all mines, seven out of eight of the bile insoluble inulin fermenters occurred in mine W.

All suspected pneumococcal cultures were injected into mice, which were killed after 24 hours. On one occasion only (out of 54 strains) was the mouse found dead after this period. On six other occasions definite capsulated pneumococci were found in the mouse peritoneal exudate. In the remainder, however, examination of the exudate failed to show any pneumococci. Typing was carried out by mixing drops of exudate with agglutinating rabbit sera for types 1, 2, and 3. In the case where the mouse died the organism proved to be a definite type 3 pneumococcus. In the other six cases where diplococci were seen in the exudate no reaction occurred with these sera and they were labelled group 4. Those remaining pneumococci, that were destroyed in the peritoneal cavity, were also labelled group 4, in the sense that they certainly were not types 1, 2, or 3. It might be more accurate, however, to call these rough, avirulent and untypable pneumococci.

It is difficult to assess accurately the importance of the presence of α cocci in the eye. With regard to the more virulent pneumococci their significance is obvious. They must be regarded as potential pathogens. The rough untypable pneumococci must also be considered of importance. Although avirulent for the mouse it is possible that they may regain their virulence in a traumatised eye (see Duke-Elder, 1938). *Streptococcus viridans* must also be viewed as a potential pathogen, as it may occur in cases of corneal ulcer (personal observations).

Diplobacillus of Morax.—This organism was detected regularly in almost all the different groups of workers. Altogether it was found in 24 persons (out of 658) but the distribution was not

regular over all the pits. Thus at pits L, V, and W it occurred in 2·3 per cent. of all workers, whereas at pit A in 6·76 per cent.

The organism was tested for its ability to liquefy Löffler's serum at 37° C., to grow on agar at 37° C. and room temperature, and for liquefaction of gelatin. Serum was liquefied by all strains while none grew on agar at room temperature nor liquefied gelatin. It was found that six strains grew quite luxuriantly on agar at 37°C. and did not lose this property on repeated subculture. Five of these particular strains occurred in workers at mine A.

TABLE II.

Colliery	A.	V.	W.	L.	Combined results
Number of men examined	189	160	149	160	658
Total *a* cocci present -	per cent. 21·2	per cent. 19·22	per cent. 17·42	per cent. 20.46	per cent. 19·35
Streptococcus viridans -	10·6	9·30	11·39	14.26	11·25
Pneumococcus - -	10·6	9·92	6·03	6.2	8·1

None of the workers examined complained of any conjunctival irritation and certainly no person with a marked degree of angular conjunctivitis was noted. It is possible, of course, that as the examination was of necessity a rapid one certain minor degrees may have been missed.

These figures show, however, that the organism is quite generally present in the conjunctival sac of mine workers and may on occasions reach a high percentage. As far as could be determined in the majority of cases the presence of the organism did not appear to evoke any conjunctivitis. Evidence will be presented in a further study that the organism may be carried temporarily. Certain Continental workers have recorded the presence of the organism in healthy conjunctival sacs. Thus Pillat (1922) has found it in 22 per cent. of persons, and v. Pelláthy (1932) in 9·5 per cent. In this country, however, it has generally been accepted that the organism is a pathogen and does not occur in healthy persons.

The presence of *diplobacillus of Morax* in the conjunctival sacs with such regularity must be regarded as of great importance, the more so in view of the fact that the organism is a well recognised causal agent of corneal ulcer.

Micrococcus catarrhalis.—This organism was isolated from 15 persons (out of 658), or 2·25 per cent. All strains grew on agar

at 37°C. The majority of strains were tested for their fermentation reactions, which were negative for glucose, saccharose, and maltose. The organism is probably a harmless commensal and little or no importance is attached to its presence. Various authors have, however, recorded its occasional presence in cases of conjunctivitis (see Duke-Elder, 1938).

Haemophilic bacilli.—These organisms were isolated from 10 persons (out of 658), or 1·5 per cent. All strains were typical Gram-negative bacilli which grew on blood agar but not on ordinary agar, and would thus normally be labelled *B. Koch-Weeks.* The organism would appear either to be carried as a harmless commensal, or to cause a mild chronic infection, as certainly no case of typical " pink-eye " was encountered. The organism is generally accepted as a pathogen and some importance should be attached to its presence. It should, however, be noted that it is not possible to differentiate between this organism and *B. influenzae.* It is possible the organisms isolated were

TABLE III

Examination of Colliery A Mine-Workers, showing percentage of persons harbouring various organisms.

	Miners		Brushers		Oncost		Surface	
Total number examined	60		50		39		40	
ORGANISMS GROWING IN PROFUSE OR MODERATE AMOUNT.								
Staphylococcus albus	43·3		18		57·2		33·3	
Diphtheroid bacilli	50		26		39		30	
ORGANISMS GROWING IN ANY AMOUNT.								
Staphylococcus citreus	10		10		20·8		—	
Staphylococcus chromogenicus	1·7		4		—		—	
a cocci: *Streptococcus viridans*	3·3	16·6	16	22	18·2	28 6	7·5	20
a cocci: *Pneumococcus* (group 4)	13·3		6		10·4		12 5	
a cocci: *Pneumococcus* (type 1, 2, or 3)	—		—		—		—	
Diplo-bacillus of Morax	6·7		6		13		2·5	
Micrococcus catarrhalis	5		4		—		—	
Haemophilic bacilli	3·3		—		10·4		—	
Anthracoid bacilli	—		—		—		—	
B. coli	—		—		2·6		—	

not true *B. Koch-Weeks* strains, but rather influenzal strains of little or no significance in ocular pathology.

B. coli.—This organism was only isolated from 5 persons, *i.e.*, 0·75 per cent. As this organism may sometimes be pyogenic its occasional presence may be of some importance.

Other organisms.—Little importance need be attached to the occasional presence of anthracoid bacilli or *micrococcus tetragenus* as they are generally devoid of pathogenic action. With regard to the former, however, it should be remembered that anthracoid organisms are commonly found in that rare condition of ring-abscess of the cornea.

The findings in individual mines.—Having now discussed the various organisms the results of each mine may be given separately.

Mine A (Table III).—Two main facts are evident from these figures. First, as already mentioned, there is a higher percentage

TABLE IV

Examination of Colliery V Mine-Workers, showing percentage of persons harbouring various organisms.

	Miners	Brushers	Oncost	Surface
Total number examined	40	40	40	40
ORGANISMS GROWING IN PROFUSE OR MODERATE AMOUNT.				
Staphylococcus albus	20	40	35	35
Diphtheroid bacilli	50	45	37·5	47·5
ORGANISMS GROWING IN ANY AMOUNT.				
Staphylococcus citreus	2·5	15	17·5	7·5
Staphylococcus chromogenicus	—	—	—	—
α cocci: *Streptococcus viridans*	7·5	5	10	15
α cocci: *Pneumococcus* (group 4)	7·5 (15)	22·5 (27·5)	5 (15)	5 (20)
α cocci: *Pneumococcus* (type 1, 2, or 3)	—	—	—	—
Diplo-bacillus of Morax	7·5	2·5	2·5	—
Micrococcus catarrhalis	—	—	2·5	—
Haemophilic bacilli	—	2·5	2·5	—
Anthracoid bacilli	5	10	2·5	5
B. coli	—	2·5	—	2·5
M. tetragenus	—	2·5	—	—

of *diplobacillus of Morax* than in any other mine. Second, comparing the various groups it is evident that the oncost-workers' conjunctival flora is more profuse than that of any other of the A workers.

Mine V (*Table IV*).—The percentage of Morax diplobacilli here is substantially smaller than at mine A although 7·5 per cent. of the miners harboured the organisms. The oncost-workers' flora is not more profuse than that of the other groups.

TABLE V

Examination of Colliery W Mine-Workers, showing percentage of persons harbouring various organisms.

	Miners	Brushers	Oncost	Surface
Total number examined	39	34	36	40
ORGANISMS GROWING IN PROFUSE OR MODERATE AMOUNT.				
Staphylococcus albus	39	34·8	47·6	60
Diphtheroid bacilli	54	11·6	56	32·5
ORGANISMS GROWING IN ANY AMOUNT.				
Staphylococcus citreus	13	14·5	11·2	12·5
Staphylococcus chromogenicus	—	—	—	—
α cocci: *Streptococcus viridans*	15·6	5·8	22·4	2·5
α cocci: *Pneumococcus* (group 4)	— (18·2)	— (5·8)	11·2 (33·6)	7·5 (10)
α cocci: *Pneumococcus* (type 3)	2·6	—	—	—
Diplo-bacillus of Morax	2·6	2·9	2·8	2·5
Micrococcus catarrhalis	—	—	5·6	—
Haemophilic bacilli	—	—	2·8	—
Anthracoid bacilli	2·6	—	2·8	2·5
B. coli	—	—	—	2·5
M. tetragenus	—	—	2·8	—

Mine W (*Table V*).—In this mine the oncost group of workers' flora is distinctly more profuse than that of the others.

Mine L (*Table VI*).—In this mine the profuse flora of the oncost-workers of mines A and W is not found, these men presenting a comparatively scanty flora.

TABLE VI

Examination of Colliery L Mine-Workers, showing percentage of persons harbouring various organisms.

	Miners	Brushers	Oncost	Surface
Total numbers examined	40	40	40	40
ORGANISMS GROWING IN PROFUSE OR MODERATE AMOUNT.				
Staphylococcus albus	30	20	42·5	20
Diphtheroid bacilli	32·5	45	40	37·5
ORGANISMS GROWING IN ANY AMOUNT.				
Staphylococcus citreus	10	5	5	7·5
Staphylococcus chromogenicus	—	—	—	—
a cocci: *Streptococcus viridans*	17·5	12·5	2·5	25
a cocci: *Pneumococcus* (group 4)	10 (27.5)	2·5 (15)	10 (12·5)	2.5 (27·5)
a cocci: *Pneumococcus* (type 1, 2, or 3)	—	—	—	—
Diplo bacillus of Morax	—	2·5	—	2·5
Micrococcus catarrhalis	5	10	—	2·5
Influenzal bacilli	—	2·5	—	—
Anthracoid bacilli	15	5	2·5	—
B. coli	—	2·5	—	—

Discussion

On general principles of bacterial ecology it was thought that there might be a tendency for an organism, once having gained access to a group of workers to spread throughout the unit. It was possible definitely to substantiate this supposition on two occasions. Thus in the case of *pneumococcus* although only eight bile insoluble, inulin fermenting, strains were isolated, seven were found in the workers at mine W. Secondly, there were isolated only six strains of *diplobacillus of Morax* growing on agar, yet five of these occurred in mine A.

From the above results it is evident that a wide range of organisms occurs in the conjunctival sacs of coal mine-workers, and generally speaking the results in all groups, whether above or below ground, are of the same order. In two pits, however, the oncost group of workers had a noticeably more profuse flora than the other workers. Apart from this there was no evidence

that workers below ground harboured a more profuse flora than did those who worked on the surface.

All groups of workers frequently harboured such pathogenic or potentially pathogenic organisms as *pneumococcus, streptococcus viridans, diplobacillus of Morax*, haemophilic bacilli, and *B. coli*. Anthracoid bacilli were also encountered. Of these organisms the first mentioned three are of particular importance, all being well recognised aetiological agents of hypopyon ulcer.

The presence of these organisms is not, however, of equal importance in the various groups of worker. Only the miners and brushers are commonly exposed to risk of corneal injury. The other workers although harbouring a similar flora rarely suffer corneal trauma. Correspondingly one finds that of any series of cases of hypopyon ulcer in mine-workers the great proportion is constituted by miners or brushers (personal observations).

It has been suggested that in certain cases of hypopyon ulcer the infective agent may enter the cornea on the traumatising particle. It is difficult to see how this could obtain in coal mine injuries as unhewn coal is probably quite sterile (personal observations). It is considered that the most reasonable explanation of the pathogenesis of hypopyon ulcer in miners is as follows:—The conjunctival sac frequently harbours pathogenic organisms and any damaging spicule of coal or stone may allow these organisms to enter and cause infection. Hypopyon ulcer occurs most commonly, therefore, in those exposed to most risk of trauma, that is the miners and brushers.

In conclusion, these studies serve to emphasise the importance of shielding the eyes of those exposed to risk of corneal injury, and if such an injury does occur the care with which it should be treated.

Summary

1. The conjunctival flora of 658 healthy coal mine-workers has been examined, representing 4 different pits.

2. In two pits the oncost-worker evidently harboured a more profuse flora than the other workers.

3. Apart from this, below-ground workers did not harbour a flora essentially different from that of surface workers.

4. The following potentially pathogenic organisms may be found in all groups of workers in significant quantity: *streptococcus viridans, pneumococcus, diplobacillus of Morax*, haemophilic bacilli and *B. coli*.

5. *Streptococcus viridans* occurred in 11·25 per cent. of persons.

6. Fifty-four strains of *pneumococcus* were encountered (representing 8·1 per cent. of the workers), but only one of these fell into a main type (type 3). The bulk of the remainder proved avirulent to the mouse, but showed typical reactions otherwise.

7. The distribution of *diplobacillus of Morax* was somewhat irregular, occurring in 2·3 per cent. of all workers in pits L, V, and W, and in 6·76 per cent. at pit A.

8. Haemophilic bacilli were isolated from 1·5 per cent. of persons, and *B. coli* from 0·75 per cent.

9. It is considered that the conjunctival flora of coal mine-workers is potentially dangerous and that the source of infection in hypopyon ulcer is from organisms already present in the conjunctival sac. Those most liable to contract the disease are those most exposed to corneal trauma—the miners and brushers.

REFERENCES

MACKIE, T. J. and MCCARTNEY. J. E —A Handbook of Practical Bacteriology. Fifth edition. Edinburgh: E. and S. Livingstone. 1938.

DUKE-ELDER, Sir W. S.—Text Book of Ophthalmology. Vol. II. London: Henry Kimpton. 1938.

PILLAT, A.—*Klin. Monatsbl f. Augenheilk.*, Vol. LXVIII, p. 533, 1922.

v. PELLÁTHY, B.—*Klin. Monatsbl. f. Augenheilk.*, Vol. LXXXIX, p. 108, 1932.

Acknowledgments

It is a pleasure to acknowledge my indebtedness to the following gentlemen, without whose co-operation the work could not have been carried out: Dr. A. H. H. Sinclair and Col. R. M. Dickson of the Ross Foundation; Professor T. J. Mackie; Dr. Douglas Inch of Gorebridge; and Dr. Gilchrist of Whitburn. Finally I wish to thank the Management, Miners' Committee and Employees of the mines concerned for their willing assistance. In every case volunteers were readily forthcoming and all expressed themselves anxious to help in every way.

STUDIES ON THE BACTERIOLOGY OF HYPOPYON ULCER

II.—The Conjunctival Flora of Shale Mine-workers

BY

*A. J. RHODES, M.B., M.R.C.P.E.

FROM THE BACTERIOLOGICAL DEPARTMENT, UNIVERSITY OF EDINBURGH

Introduction

THE work reported in this paper is a direct continuation of my previous study on the conjunctival flora of coal mine-workers (Rhodes, 1938). The object of this work is to elucidate the aetiology of hypopyon ulcer, especially in miners. An examination has been made of some 187 shale mine-workers in two different pits in central Scotland. The examinations were carried out in the months of October and November.

The working conditions in these two shale mines are almost identical, and differ greatly from those in the coal mines which I have visited. The manner of working shale is as follows. The shale is blown out of the seam by explosives, and the miner then hews out the pieces dislodged by the explosion with a pick. The shale is loaded into hutches which are transported by the oncost-workers to the main haulage roads. These roads, as well as the hewing places (stoopings), are high and airy. The whole working conditions are clean and relatively free from dust.

Methods

As before, the workers were examined at the pit head as they came off their shift. Screw-topped bottles of blood agar were used and examined for growth as in the previous study.

There are only three main classes of shale worker: surface, oncost, and miner. No difficulty was experienced in examining sufficient numbers of oncost-workers and miners, but owing to the relatively few men employed some difficulty was experienced with the surface workers. Ultimately it was decided to fuse the results of the examinations of surface workers from the two pits, thus giving the usual total of 40. The surface men comprised the usual mine labourers and skilled tradesmen, as well as men employed in " tumbling the shale " out of the hutches.

* Working under the auspices of the W. H. Ross Foundation for the Study of Prevention of Blindness, Edinburgh.

Results

Organisms isolated. *Staphylococcus albus* and diphtheroid bacilli.—These organisms were isolated with considerable frequency. The presence of the organism is noted only if it occurred in moderate or profuse amount (see Tables II and III). The results are of the same order as previously reported in coal miners. It would appear as if these organisms occurred with greater frequency at the D mine than at W.

Other commensals.—*Staphylococcus citreus,* anthracoids, *micrococcus tetragenus* and *micrococcus catarrhalis* were isolated on occasions, but little importance need to be placed on their occurrence.

Pathogens.—Table I shows the percentage of the various pathogenic organisms isolated from shale workers, compared with the findings in coal-workers.

Alpha cocci.—The table (I) shows a slightly lower percentage of alpha cocci than in coal workers. These organisms were tested for their ability to produce green pigmentation on boiled blood, for their bile solubility, and inulin fermentation. Cultures suspected to be pneumococcal were injected into mice and typing carried out. Strains proving bile insoluble and not fermenting inulin were classified as *streptococcus viridans,* and were isolated in a lower percentage of persons than in coal mines.

Pneumococcus.—Group 4 pneumococcus was isolated from a slightly higher percentage of shale than coal workers. Only 2 of the 18 strains were visible in the mouse peritoneal exudate after 24 hours. Neither of these reacted to type sera 1, 2, or 3. These findings parallel those in coal workers where the majority of strains were avirulent and untypable.

TABLE I

Showing the percentage of Coal Workers and Shale Workers harbouring various pathogenic organisms.

	Coal	*Shale*
	per cent.	per cent.
Total alpha cocci	19·35	16·43
Streptococcus viridans	11·25	6.89
Pneumococcus	8·1	9·54
Diplobacillus of Morax — Pit A	6·76	1·59
Diplobacillus of Morax — Others	2·3	—
Haemophilic bacilli	1·5	1·06
B. Coli	0·75	2·65

Eleven of the 18 strains (61·5 per cent.) gave the classical reactions of the pneumococcus while the remainder (38·5 per cent.) fermented inulin, but proved bile insoluble. It will be recalled that bile insoluble strains were also encountered in coal workers.

Diplobacillus of Morax.—At first sight this figure appears lower than that in coal workers. When analysed, however, all the strains were found to occur in miners, giving a figure of 5 per cent. at mine D and 2·5 per cent. at W. Shale miners therefore harbour the organism with approximately the same degree of frequency as coal miners.

Other pathogens.—Haemophilic bacilli and *B. coli* were also isolated and the *B. coli* figure was seen to be higher in shale workers.

Individual mines.—Mine D (Table II).—The important point to note is that the miner evidently harbours a significantly higher percentage of alpha cocci (especially pneumococci) and *diplobacillus of Morax* than the other workers. Further, it will be seen that D workers show a higher percentage of organisms generally than do W workers. This is of some interest, as the conditions

TABLE II

Showing percentage D Shale Mine-Workers harbouring various organisms.

	Miners	Oncost	Surface
Total number examined	40	40	40 (both pits merged)
ORGANISMS GROWING IN PROFUSE OR MODERATE AMOUNT.			
Staphylococcus albus	40	40	32·5
Diphtheroid bacilli	62·5	42 5	35
ORGANISMS GROWING IN ANY AMOUNT.			
Staphylococcus citreus	7·5	7·5	2·5
Staphylococcus chromogenicus	—	—	—
α cocci: *Streptococcus viridans*	2·5	5·0	12·5
α cocci: *Pneumococcus* (group 4)	20 (22·5)	10 (15)	5 (17 5)
α cocci: *Pneumococcus* (type 1, 2, or 3)	—	—	—
Diplo-bacillus of Morax	5	—	—
Micrococcus catarrhalis	—	—	—
Haemophilic bacilli	—	—	2·5
Anthracoid bacilli	—	2·5	—
B. coli	2·5	5	—

of work were very closely similar. *Mine W (Table III).*—The figures in this mine are lower than those for mine D for the majority of organisms. W miners, however, do not have a higher percentage of alpha cocci than other workers, rather their figure is lower.

TABLE III

Showing percentage of W Shale Mine-Workers harbouring various organisms.

	Miners		Oncost		Merged Surface	
Total numbers examined	40		27		40 (both pits)	
ORGANISMS GROWING IN PROFUSE OR MODERATE AMOUNT.						
Staphylococcus albus	15		33·3		32·5	
Diphtheroid bacilli	*25*		*37*		*35*	
ORGANISMS GROWING IN ANY AMOUNT.						
Staphylococcus citreus	2·5		—		2·5	
Staphylococcus chromogenicus	—		—		—	
α cocci: *Streptococcus viridans*	7·5	12·5	7·4	14·8	12·5	17·5
α cocci: *Pneumococcus* (group 4)	5		7·5		5	
α cocci: *Pneumococcus* (type 1, 2, or 3)	—		—		—	
Diplo-bacillus of Morax	2·5		—		—	
Micrococcus catarrhalis	5		—		—	
Haemophilic bacilli	—		—		2·5	
Anthracoid bacilli	—		—		—	
B. coli	2·5		3·7		—	
Micrococcus tetragenus	5		—		—	

Discussion

A wide range of organisms has thus been isolated from shale workers, as it was from coal workers. With regard to the pathogenic organisms there would not seem to be any important difference between coal and shale workers. Those exposed to most risk of traumatism, the miners, harbour alpha cocci and *diplobacillus of Morax* in significant quantity. Shale oncost-workers do not appear to harbour *diplobacillus of Morax*, although this was found regularly in coal oncost-workers.

The tendency for organisms to spread throughout a unit was observed in shale workers as in coal workers. Thus, only 7 strains of bile insoluble, inulin fermenting pneumococci were found in the two pits examined. Yet of these 7 strains 6 occurred in the miner group.

Further, it should be noted, on a larger scale, that the D workers harboured a more profuse flora than the W men, although the working conditions appeared identical.

Shale mine workers therefore harbour a flora consisting partly of potential pathogens. This fact is of most importance in those most exposed to traumatism. A spicule of shale entering the miner's cornea may afford the necessary breach of surface for these organisms to enter and cause infection. The opinion is again expressed that the source of infection in hypopyon ulcer is from organisms already present in the conjunctival sac, and that the mine worker's conjunctival flora definitely exposes him to the risk of infection.

Summary

1. The conjunctival flora of 189 shale workers has been examined.

2. Shale workers harbour significant quantities of potential pathogens such as *streptococcus viridans, pneumococcus* (group 4), *diplobacillus of Morax*, haemophilic bacilli and *B. coli*.

3. The evidence adduced is additional support for the belief that the source of infection in hypopyon ulcer is already present in the conjunctival sac, and that the mine worker's conjunctival flora definitely predisposes him to infection.

REFERENCE

RHODES, A. J.—*Brit. Jl. of Ophthal.*, January, 1939.

Acknowledgments

It is a pleasure once again to acknowledge the help afforded by Dr. A. H. H. Sinclair and Col. R. M. Dickson of the Ross Foundation and by Professor T. J. Mackie. I have to thank Dr. Scott of Broxburn for kindly making all local arrangements for my visits to the shale mines. Finally, the Management and Employees of the mines did all in their power to assist, and volunteers were always forthcoming.

A NOTE ON THE USE OF HORSE HAIR SUTURES FOR THE CONJUNCTIVA

BY

PERCIVAL J. HAY

SHEFFIELD

I HAVE found horse hair extremely useful for closing the wound after inserting the glass globe in a Frost-Lang operation. No knots are required. It keeps the wound firmly closed in virtue of its rigidity, while it does not bunch up the conjunctiva like a silk purse-string suture.

A good grip is taken of the conjunctiva beyond one end of the wound (Fig. 1), and the horse hair on a Mersuture needle passed from below upwards, then in and out along the lips of the wound,

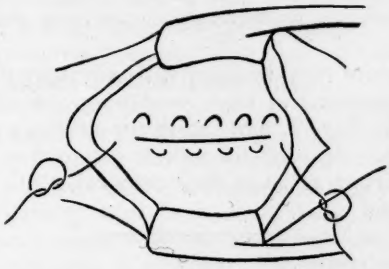


FIG. 1.

Horse hair suture for closing the wound after a Frost-Lang operation.

keeping about 3 to 4 mm. from the margin, finally down and out beyond the other end of the wound. The suture is now drawn taut and a loop made at each end, placing it so as to lie *outside* the lids when the eye is closed. The loops prevent the suture from being pulled out accidentally. Their position can be adjusted by placing the point of a closed artery forceps in the loops and running them to their proper position. When the wound has healed, and the time has come to remove the suture, *i.e.*, in about a week, all that is required is to cut one end close to the conjunctiva, pull quickly at the other end, and the suture is out almost before the patient is aware of it.

In times gone by I used to suture the recti or Tenon's capsule separately with catgut, and then the conjunctiva with silk. The cosmetic appearance and the movement subsequently imparted to the artificial eye is, however, quite as good by the method just described as by the older time-consuming one. In addition, if

the size of the glass globe has been properly judged, it will stay in because a broad and continuous surface of contact is secured between the lips of the wound.

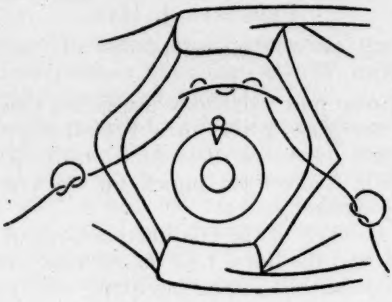


FIG. 2.

Horse hair suture for closing the conjunctival wound after trephining.

The same suture may be used with advantage for closing the wound in the conjunctiva after trephining. It is passed in and out as shown in Fig. 2, and, as in the previous operation, it is easily removed. No difficult silk knots to find and cut! No cocaine necessary to assist in their removal.

THE PATHOLOGY OF SCLERAL PLAQUES

Report of five cases of degenerative plaques in the sclera mesially, one studied histologically

BY

ARTHUR M. CULLER, M.D.

DAYTON, OHIO

UNDER the heading, " Bilateral mesial superficial deficiency of the sclera," Basil Graves[1, 2] has recently described two cases of this disease. I have encountered this condition (which on casual observation I thought might be a hyaline change in the insertion of the internal rectus muscle) and found that the edge of the lesion lay approximately 3 mm. behind the mesial conjunctival limbus. It presented the appearance under the slit-lamp of a minute squared hole in the outer layers of the sclera through which the underlying ciliary body could be seen. A slightly congested conjunctiva was neither elevated nor depressed over the lesion.

The area was of the same slate gray colour as a scleral staphyloma but the borders were sharply demarcated, giving a punched out appearance. There is nothing to add to Graves' accurate description. I have fortunately obtained an autopsy specimen of the lesion.

Case I.—M.C., a female, aged 79 years, was seen in consultation with the Medical Department of Good Samaritan Hospital. Her fundus showed well marked arteriosclerosis of the retinal vessels, and incipient cataract was present. Externally there was a broad gerontoxon completely encircling the cornea. In each eye was a dark area in the sclera which has been described above. The measurements of the areas were as follows: O.D. conjunctival limbus to mesial border of the lesion 3·2 mm.; vertical mean diameter 5·4 mm.; horizontal mean diameter 2·0 mm.; O.S. limbus to mesial border 2·9 mm.; vertical mean diameter 3·3 mm.; horizontal mean diameter 1·3 mm.

The patient succumbed after a long illness and permission was obtained for a scleral specimen at autopsy. The important autopsy findings were as follows: arteriosclerotic heart and kidney disease, cachexia, and terminal pneumonia.

A specimen approximately 6 mm. in diameter was removed from the mesial aspect of the sclera of the right eye. The apparent hole, 5·5 mm. by 2·0 mm. was filled with a transparent hardened seed-like mass which exhibited a marked tendency to break away from the surrounding sclera and could have been shelled out. Fat stains were not done. The specimen was fixed in 10 per cent. formalin, and imbedded in paraffin. Serial sections were stained with haematoxylin and eosin or Cajal's connective tissue stain.

In the sections the conjunctiva and episclera were atrophic. A few globules filled with granular debris were seen lying immediately under the epithelium. The sclera was 0·6 mm. in thickness at the edge of the specimen but became gradually thinner as the lesion was approached. The borders of the lesion were slightly elevated, perhaps largely due to artefact, but the sclera in the centre of the lesion was only 0·3 mm. in thickness. The lesion itself was sharply demarcated. The temporal border (towards the cornea) (*Fig.* 1) dipped into the sclera in a gradual curve (*Fig.* 2), until in the centre of the lesion the strand of sclera forming the base was less than one-tenth the thickness of the lesion (*Fig.* 3). The mesial border was more nearly perpendicular (*Fig.* 4). The lesion stained deeply. It was composed of a large mass of granular debris which was entirely free from cellular structure and contained large masses of hyaline. No clefts or vacuoles could be made out either in the mass or in the surrounding sclera which might have resulted from the presence of lipoid degenerative changes. There were no calcium deposits.

Surrounding the degenerative plaque was a zone approximately 0·5 mm. broad in which the connective tissue fibres appeared swollen, and the nuclei for the most part had disappeared. Individual fibres could be made out passing abruptly into the mass of hyaline.

Case II.—L.S., a female, aged 79 years, presented herself on December 13, 1937, because of burning of her eyelids. She was refracted, obtaining 6/7·5 vision in both eyes. Ophthalmoscopic examination showed some sclerosis of the nucleus and a few riders in the lens of each eye, and well marked tortuosity and variation in the calibre of the arteries. There was a moderate hypertrophic conjunctivitis. The lids were flaccid. There was a prominent gerontoxon and slate gray, roughly rectangular areas were present in the sclera mesially in both eyes. The borders of the lesions were quite sharp although this was variable (*Fig.* 5). The measurements were as follows: O.D. limbus to mesial border of the plaque 3·7 mm.; vertical mean diameter 3·3 mm.; horizontal mean diameter 1·0 mm.; O.S. limbus to lesion 3·5 mm.; vertical mean diameter 2·5 mm.; horizontal diameter 1·3 mm.

Case III.—G.T., a female, aged 85 years, presented herself with a contact dermatitis of the lids on April 16, 1938. Her corrected vision was O.D. 6/7·5, O.S. 6/12. Ophthalmoscopic examination revealed scattered flaky opacities in the cortex of the lens and exaggerated arteriosclerosis of the retinal vessels in both eyes. There were broad circular gerontoxons in both eyes and each presented a slate gray area in the sclera mesially. The right was much broader below than above and the borders were less sharp. The left lesion was narrow in the centre so that it appeared two-lobed (*Fig.* 6). O.D. conjunctival limbus to mesial border of the lesion 3·0 mm.; vertical measurement 5·0 mm.; horizontal 2·0 mm. O.S. limbus to lesion 3·9 mm.; vertical measurement 4·2 mm.; horizontal diameter 2·1 mm.

Case IV.—M.H., a female, aged 82 years, consulted me on November 1, 1937, because of failing vision in both eyes. She had moderately contracted visual fields. Her corrected vision was 6/60 in both eyes. The fundus showed some cupping of the disc and incipient cataracts in both eyes. Intra-ocular tension was O.D. 35, O.S. 32 (Schiötz). External examination showed only a slight arcus senilis. In the mesial aspect of the sclera of the left eye there was an oval, punched out dark area. The mesial border was 3·1 mm. from the limbus. The vertical diameter was 1·2 mm. The horizontal diameter was 0·9 mm. The right eye showed no well defined dark area, although under the slit-lamp superficial changes in the sclera could be made out.

Case V.—D.F., a male, aged 72 years, complained on September 7, 1937, of occasional attacks of blurred vision during which

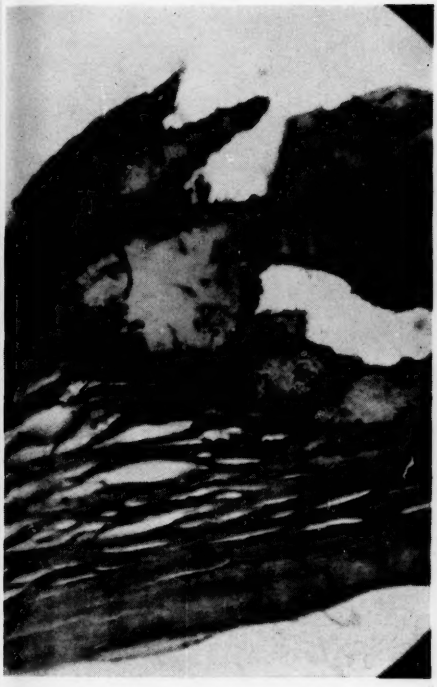


FIG. 1.

Photomicrograph × 150. Section through the left border of the lesion from the right eye of Case 1. Swollen fibres of the sclera can be seen passing into a friable mass of cellular debris.

FIG. 2.

Same magnification of the adjacent portion of the lesion.

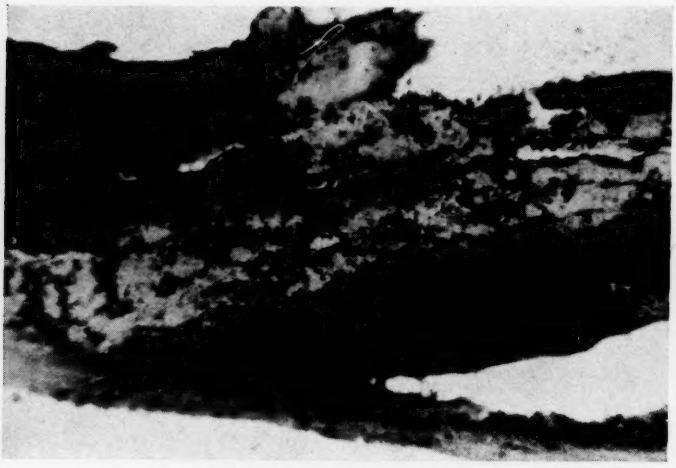


FIG. 3.

Low power magnification of the centre of the lesion showing only a thin strand of comparatively normal scleral tissue adjacent to the choroid at the base of the degenerative plaque. (×150.)

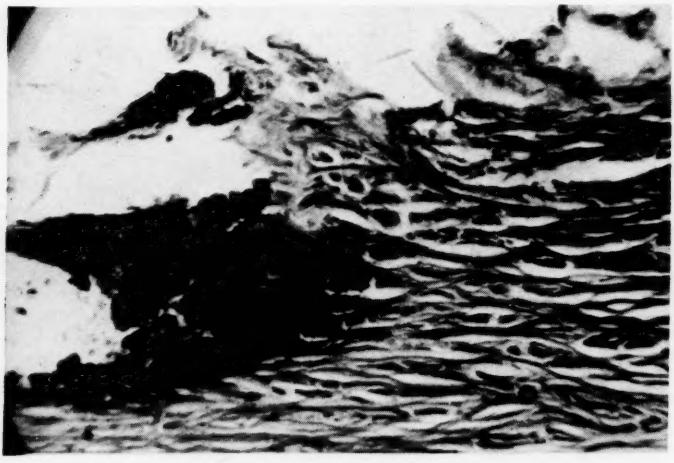


FIG. 4.

The right border of the lesion in the same section. This border is more nearly perpendicular. The hyaline mass has broken away from the sclera in the superficial portion. (×150.)

FIG. 5.

Photograph (×1·5) of the right eye of Case 2, showing the slate gray rectangular plaque in the sclera mesially.

FIG. 6.

Photograph of the left eye of Case 3, showing the two lobed lesion in the sclera mesially Conjunctival vessels dilated by the light necessary for the photograph partially obscure the lesion.

FIG. 7.

Photograph of the left eye of Case 4, showing the dark oval spot in the mesial aspect of the sclera.

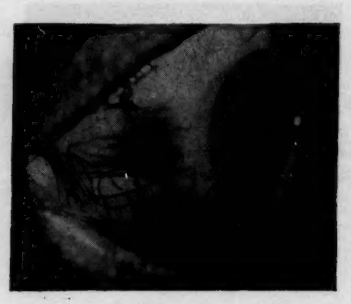


FIG. 8.

Photograph of the left eye of Case 5, showing the rectangular defect in the sclera. This has less sharp borders than the other cases but is more conspicuous clinically than in the photograph because of the colour contrast.

he saw halos around lights. No flashes of light and no pain were apparent. His right eye had been enucleated at the age of 16 years, because of trauma. His visual acuity in the left eye was 6/30 corrected to 6/7·5. The fundus showed shallow cupping of the disc and a posterior cortical radiating opacity at "1.30 o'clock." Visual fields showed a sickle-shaped scotoma above and below the blind spot. Intra-ocular tension was 45 (Schiötz). Externally there was a well marked arcus senilis and a large rectangular dark area in the sclera mesially. The borders of the lesion were everywhere less abrupt than in the other cases. The measurements were as follows: limbus to lesion 4·2 mm.; vertical diameter of lesion 5·2 mm.; horizontal diameter 2·6 mm.

Comment

While these lesions are small, they are rather conspicuous clinically because of the colour. Photographs do not show them well because of scleral scatter. Under the slit-lamp the borders of the lesions are usually sharp and in places slightly shelved. This was obscured by the dispersion of light in all of my attempts at slit-lamp photographs.

The two cases described in detail by Graves were respectively 60 and 70 years of age. The cases described here were all over 70. One might expect degenerative lesions to occur in this age group more frequently than in those under 60 years of age. The histological appearance is clearly a degenerative change.

Rones[3] in a comprehensive survey of senile changes in the

eye does not mention this condition and states that senile changes in the sclera are chiefly in the nature of fatty infiltration.

Graves mentions having seen six or seven cases of this disease. Probably it is not at all rare but has failed to appear in the literature previously because it is apparently clinically insignificant. However, the photomicrographs of the case studied histologically show how near the sclera is to perforation.

Van der Hoeve[4] has described an entity, scleromalacia perforans, which arises in degenerative plaques in the sclera. The question arises whether Graves' scleral spots are not the early stage of the same disease.

Verhoeff and King[5] in a study of the literature from which they have collected fourteen cases, and of their own case, have composed a description of the clinical course of scleromalacia perforans. I quote from their paper. "In one or both eyes there develop simultaneously or at intervals, slightly elevated nodules involving the sclera and overlying tissue and situated anywhere between the corneal limbus and equator. Congestion is moderate and is limited to the nodules and their immediate vicinities. After a considerable period of time, in some cases six months or longer, one or more of the nodules may disappear. At the former site of the nodule there is seen in the sclera a shallow cavity, often of large size. Over a cavity the conjunctiva may be intact or absent. When, as rarely happens, a lesion is situated at the corneal limbus, it may perforate into the anterior chamber, and produce a cystoid nodule such as occurs after trephining. Into this nodule, the iris may or may not be herniated. When situated elsewhere, the lesion seldom if ever perforates the sclera and the remaining tissue usually withstands the intraocular pressure, rupturing only in rare instances. Evidences of intraocular inflammation are relatively slight or entirely lacking, unless as rarely happens, purulent infection occurs at the site of a cavity. Pain may be absent.

"Posterior synechiae, atrophy of the iris, or cataract, may occur as late complications in marked cases. Usually the ocular disease does not occur before the patient reaches the age of fifty years. In the great majority of cases definite evidences of rheumatoid arthritis exist at the onset of scleritis."

From the histological findings in their case they believe the process is comparable to the subcutaneous nodules of rheumatoid arthritis. They postulate a metabolic disturbance which produces a deposition of some chemical substance in the sclera. A sharply defined area of necrotic tissue appears. "This becomes surrounded by a wall of epithelioid cells and slowly infiltrated with pus cells. This process results in the formation of a sequestrum which becomes completely disintegrated and densely infiltrated

with necrotic pus cells." Verhoeff believes that cavities are due to perforation and discharge of the sequestrum, though the necrotic tissue is sometimes replaced by fibrous tissue without cavity formation.

There are obvious differences in the clinical picture of these tiny degenerative plaques and scleromalacia perforans. None of my patients suffered from serious arthritis. In none were nodules ever present on the sclera. On the other hand, these lesions have not been described in any other location than between the insertion of the internal rectus and the limbus, whereas the nodules of the early stage of scleromalacia perforans may occur anywhere in the sclera which is covered with conjunctiva. These differences are irreconcilable. One must conclude that recent literature has added two new lesions of the sclera, both primarily degenerative in character.

Summary

Graves' scleral plaques occur principally in patients over sixty years of age. Approximately 3 mm. behind the corneal limbus mesially, irregularly rectangular translucent plaques in the superficial layers of the sclera may occur. These vary in size from pinpoint to approximately 2 mm. in the horizontal plane and 6 mm. in the vertical plane and are usually bilateral. They are slate gray in colour because of the ciliary body showing through the area of increased transparency. They do not grossly disturb the neighbouring conjunctiva or ciliary body. A distinguishing characteristic is the definite tendency to square cut borders. To the descriptive name applied by Graves, " Developmental bilateral mesial superficial intagliated deficiency of the sclera," can only be added that the histological appearance is that of a degenerative change rather than a developmental defect. No clinical symptoms are known to arise from the lesions. Scleromalacia perforans does not arise in these degenerative plaques in the sclera.

BIBLIOGRAPHY

1. GRAVES, BASIL.—Bilateral mesial superficial deficiency of the sclera. *Brit. Jl. of Ophthal.*, Vol. XXI, No. 10, p. 534, October, 1937.
2. ——— Diseases of the Cornea. "The Eye and its Diseases." Berens, pp. 467-8. (Saunders, 1936.)
3. RONES, BENJ.—Senile changes and degenerations of the human eye. *Amer. Jl. of Ophthal.*, Vol. XXI, No. 3, pp. 243-4, March, 1938.
4. VAN DER HOEVE, J.—Scleromalacia Perforans. *Arch. of Ophthal.*, Vol. XI, p. 111, January, 1934.
5. VERHOEFF, F. H., and KING, M. J.—Scleromalacia Perforans: Report of a case studied clinically, bacteriologically and histologically. *Trans. of the Section of Ophthal.*, 1938. (In Press.)

LIGHT ADAPTATION AT THE FOVEA FOR NORMAL EYES

BY

W. D. WRIGHT, D.Sc., A.R.C.S.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

Aim of the Investigation

As a result of experiments on the foveal adaptation process by the method of binocular matching[1, 2], it seemed likely that data obtained from observers with defective vision might lead to further knowledge of the retinal processes and of certain diseases of the eye and might in some cases assist in their diagnosis. Before this possibility could be tested, it was essential to determine the differences that might exist among apparently normal eyes, for without this information the significance of variations from the normal could not be assessed. The results given below are therefore, in a sense, preliminary observations, but they have proved to be of considerable interest in themselves, apart from their value in connection with any subsequent investigation.

The earlier work quoted above was carried out using an elaborate trichromatic colorimeter with which both intensity and colour changes induced by various adapting conditions, were recorded. To avoid prolonging the investigation unduly, the number of observers had to be strictly limited and in practice nearly all the observations were made by the author. In order that a much greater number of observers might be tested, it was necessary to restrict the scope of the observations and to simplify them as far as possible, both to save time and to ensure that those not familiar with visual observations would have the minimum of difficulty in carrying out the tests. For this purpose a subjective photometer[3] was constructed with which tests could be carried out using a single adapting radiation and recording intensity changes alone. With this instrument, over 100 observers have been tested and it is with the analysis of these results that this paper is concerned.

Apparatus and Technique

A first model of the subjective photometer has been described elsewhere.[3] This instrument was used for the initial observations, but an improved apparatus was designed and used in the majority of the tests reported below. The later instrument is illustrated in Figs. 1 and 2.

A calibrated " fullolite " lamp L is mounted in the lamphouse H and used to illuminate two optical systems via the aperture A_1 for the right eye system and the aperture A_2 and the mirror M for the left eye system. Each system consists essentially of a

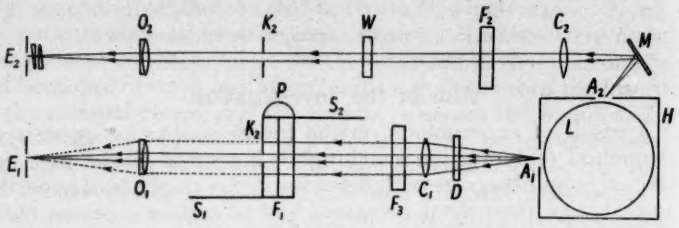


FIG. 1.

Optical system of subjective photometer.

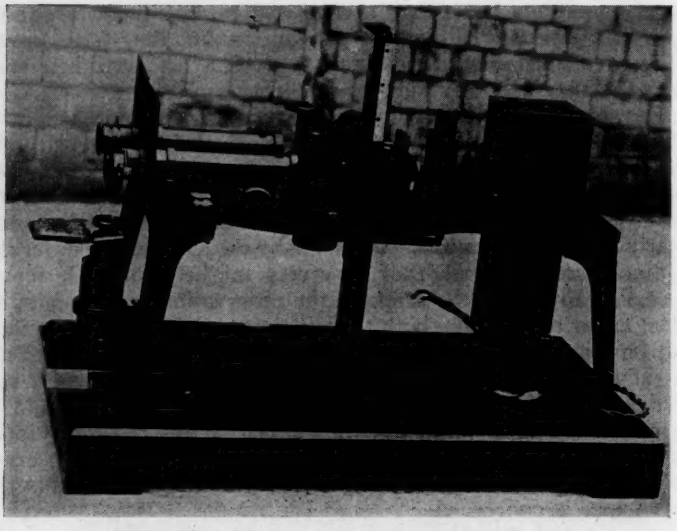


FIG. 2.

General view of subjective photometer.

collimating lens, C_1, C_2, and an observing lens, O_1, O_2. Light from the surface of the lamp is rendered parallel by C_1 and C_2 and brought to a focus by O_1 and O_2 at the two exit-pupils, E_1 and E_2. These consist of holes drilled in the end plates of the observing tubes. Filter holders are provided in each beam for

suitable neutral filters and colour filters. A calibrated photometric wedge, W, is mounted in the left eye beam to enable the observer to vary the intensity of that beam by known amounts.

The test fields are defined by two horizontal rectangular apertures, K_1, K_2, of a size such that they subtend an angle of approximately $1° \times 2°$ at the eye. Their colour and intensity are controlled by filters at F_1 and F_2. When making binocular matches it is desirable that the test patches should only be viewed momentarily, otherwise the eye tends to become to some extent adapted to them, and their apparent brightness will be correspondingly modified. As a general rule, it is found to be satisfactory if the patches are viewed for one or two seconds in every

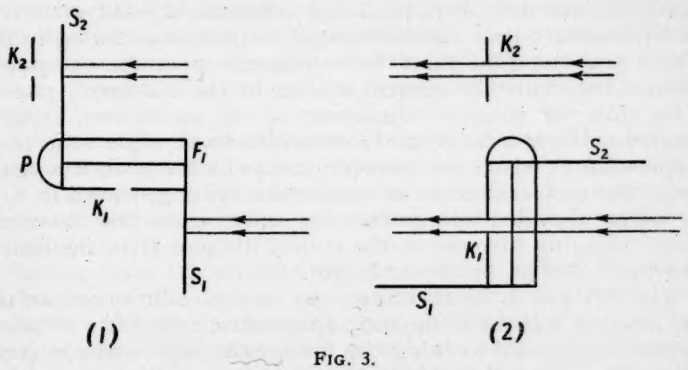


FIG. 3.

Operation of shutters on photometer.

ten seconds and this is allowed for, by mounting the aperture K_1 and the filters at F_1 on a pivot P. This pivot can be operated by a knurled head underneath the main platform on which the apparatus is mounted and can be rotated by hand through a right angle. Attached to F_1 are two shutters, S_1 and S_2, and when P is rotated, K_1 and F_1 move out of the field of view and simultaneously S_1 and S_2 move in front of the right and left beams respectively to leave an unilluminated field in each eye. The two positions of P are illustrated diagrammatically in Fig. 3. A spring beneath the table maintains the shutters normally in position 1 of Fig. 3, so that the test fields only become visible when P is rotated to position 2. When necessary the mechanism can be fastened by a catch in the latter position, to leave the test patches permanently in the field of view.

The adapting field is introduced by raising the shutter S_1 when in position 1. This allows the whole of the light from C_1 to

enter O_1, so that the right eye views a circular field about 6° angular subtense, the left eye remaining dark. The colour and intensity of the adapting field can be controlled by a filter at F_3 and a daylight filter at D. In the experiments to be described a white adapting field was employed and this, of course, was independent of the filters at F_1. On the other hand, the right eye test patch was controlled by both the filters at F_1 and at F_3, and the filters at F_1 had to be selected after the action of those at F_3 had been allowed for.

The distance between the exit-pupils, E_1 and E_2, has to be adjustable to suit the inter-ocular distance of each individual. This is provided for by mounting the two optical systems on rectangular bars pivoted at one end. Adjusting screws and springs allow each bar to be moved independently and when correctly adjusted, they can be clamped in position. Owing to the Stiles and Crawford effect, it is important that the exit-pupils should be accurately centred relative to the observer's pupils. This calls for accurate adjustment of the pupils and, equally important, rigid location of the observer's head. The wax dental impression on which the observer bites to fix his head, was again used, but was attached to an improved mounting, shown in Fig. 2, which provided adjustments for squaring-on the observer's head, bringing his eyes to the correct distance from the instrument and also to the correct height.

The left eye is centred first, the vertical adjustment on the mouth-piece and the horizontal adjustment on the left eye optical system being used to bring the instrument pupil and eye pupil on to the same axis. This adjustment is controlled by viewing a coarse grating placed in the field of view and illuminating it by light which has passed through a purple cobalt filter. When the pencil of light emerging from the exit-pupil does not pass centrally through the cornea, some unsymmetrical chromatic aberration is introduced by the eye, which causes the bars of the grating to be illuminated on one side by red light and on the other by blue. The effect is, of course, apparent when white light is used, but is more marked and the adjustment is more sensitive, with the cobalt glass. A vertical grid is used to test for horizontal alignment, a horizontal grid for vertical alignment. It is estimated that the adjustment can be repeated at least to within 0·25 mm.

Having centred the left eye, the position of the mouthpiece mounting can no longer be altered to centre the right eye. This adjustment has to be made solely by moving E_1, and the chief movement required is a horizontal one to give the correct inter-ocular separation. Provided the observer's eyes and mouth are reasonably symmetrical, the vertical adjustment required is not

usually more than 2 or 3 mm., and this displacement of E_1 is sufficiently small to be provided by a simple vertical movement of E_1 off the axis of the system, without risk of producing any vignetting or change in intensity of the field. In one or two cases when a bad dental impression had been made, it has been necessary to make a second impression, in order that the right eye could be centred within the limits of motion provided in the apparatus.

The remaining adjustment is one to bring the two test patches apparently vertically above one another when seen simultaneously. A small vertical separation is also convenient to prevent binocular rivalry and to remove all chance of fusion of the two patches. As the relative positions of the patches is governed by the state of convergence of the two eyes, the adjustment must be made with the eyes as nearly at rest as possible. The actual control of the position of the patches is obtained through two prisms mounted just in front of E_2, each prism being capable of independent rotation.

At first sight these adjustments appear formidable, but an observer familiar with what is required can complete the settings in 3 or 4 minutes. For new observers, some fifteen minutes may be needed and rather more if the making of the dental impression is included.

Having made the adjustments, the observer is then allowed to dark adapt for 20 minutes, curtains being used to prevent light from the apparatus reaching his eyes. At the end of this period, the first observation is recorded, namely the setting of the photometer wedge when both patches appear of the same intensity. Three settings are made and, as mentioned above, the patches are only viewed for 1 or 2 seconds in every 10. The right eye is now light adapted for 3 minutes and at the end of this time, the test patches are viewed periodically for 1 second in every 10, and the photometer wedge is adjusted until the test patches again appear equally bright. Three readings are again recorded. Finally, the adapting field is removed and the test patches are brought permanently into the field of view. A series of rapid matches are then made to record the recovery of sensitivity of the right eye, the time of each reading being noted with a stop watch. When this observation has been made, the observer is given 10 minutes' rest, after which the whole of the observations from the commencement of the light adaptation, are repeated. A complete sitting, including adjustments and dark adaptation, occupies about $1\frac{1}{2}$ to 2 hours.

In nearly all the cases reported here, the observer had two sittings on different days, the occasions sometimes being separated by several weeks. In a few cases, when the agreement between

the two sets of results was unsatisfactory, a third sitting was held.

The white adapting radiation that was used had a colour temperature of about 4,400° K and gave a retinal illumination of 6,000 photons. The test patches were red, as given by Ilford's red spectral filters, and had a retinal intensity of about 30 photons.

In presenting and discussing the results the following symbols have been used:

A	...	adaptation intensity.
a	...	apparent brightness of test patch when both eyes dark adapted.
a_0	...	apparent brightness of test patch immediately after light adapting the right eye.
a_t	...	apparent brightness of test patch at time t, in seconds, from the end of the light adaptation.
p	..	the intra-ocular factor, that is, the sensitivity of the right eye compared to the left with both eyes dark adapted.
$q=a/a_0$		the adaptation factor, that is, the ratio between the apparent brightness of the test patch before and after light adaptation.

In all the observations the value of a was arbitrarily adjusted to be equal to 1,000. To do this the instrument reading obtained from the photometer wedge calibration, had to be multiplied by a factor which depended on the relative sensitivities of the two eyes. With both eyes equally sensitive, the scale was arranged for convenience to give a reading of 1,000 directly. If the right eye were twice as sensitive as the left ($p=2$), then twice as much light would be required in the left as in the right eye to give a photometric match, that is to say, the instrument reading would be 2,000. Hence p is derived by dividing the instrument reading by 1,000. The values of a_0 and a_t were similarly adjusted to refer to a test patch having an initial intensity of 1,000, that is, the instrument readings were multiplied by $1/p$.

The reading at which two equally sensitive eyes would make a match was found by matching (binocularly) each beam in turn against a third reference patch.

Validity and Significance of the Observations

The three most important pieces of information to be obtained from the observations are (1) the relative sensitivity p, of the two eyes when in the same state of adaptation; (2) the change in sensitivity produced by a given state of adaptation, *i.e.*, q; and (3)

the shape of the recovery curve showing the course of recovery back to the initial sensitivity.

The evaluation of the relative sensitivity of the two eyes from the magnitude of p is obviously straightforward, but the accuracy to which p can be determined is not high. Variations of 20 or 30 per cent. are quite common when repeating observations from day to day, even by persons familiar with the apparatus. These variations may arise from actual changes in the sensitivity of the eyes, from errors in adjustment or from changes in the apparatus, but the last mentioned could contribute only a small part of such a large uncertainty. Values of p which differ from unity only by small amounts are therefore of little significance, but when p is greater than 2 or less than $\frac{1}{2}$, some physiological abnormality may be indicated. Occasionally cases may arise where for some reason the response in one eye tends to inhibit that in the other, in which case only one patch can be seen at a time. If the light to the dominant eye is then obstructed, the patch in the other eye immediately becomes visible, so that a comparison of the sensitivities of the two eyes may have to be made by viewing each patch alternately and matching by memory.

While the reality and significance of p is hardly in doubt, the interpretation to be placed on q is a matter for some speculation. The underlying justification of the binocular matching method is that the left eye is not materially affected by the light adaptation in the right eye and can accordingly be used to provide a reference scale. It is unlikely that this condition is strictly satisfied, but it is possible to make one or two tests which demonstrate that whatever changes may be induced in the left eye, they are relatively unimportant. Thus if, while viewing a test patch in the left eye, a bright light is projected into the right eye, the brightness of the test patch shows no appreciable change. Neither is any significant change produced when the bright light is removed. The accuracy of a comparison made in this way is not high, but a change in sensitivity of 20 per cent. should be easily visible. Again, if a yellow test patch is viewed in the left eye and a red adapting light is thrown into the right eye, no noticeable colour change is induced in the test patch, in spite of the fact that the eye is very sensitive to any changes in hue in a yellow test colour. When very faint test patches are used some small changes do become apparent, which would suggest that something in the nature of a faint after-image is formed in the unadapted eye. It is, however, of little practical importance owing to its small magnitude.

One objection to recording q with the subjective photometer instead of a colorimeter is that, although the colour of the test patch in the left eye is effectively unchanged by the adaptation

in the right eye, the same does not strictly hold for the right eye test patch, even with the white adaptation. The colour change is not large, but it is easily seen that the two patches are not quite the same colour, at least in the early stages of the recovery curve. This leads to a further lowering of the accuracy of the observations which, in view of the inherent difficulties in binocular matching, is obviously not comparable to that obtained in normal photometer. Hence binocular matching with the subjective photometer can only be applied to measurements of gross effects, but that proves to be hardly any limitation at all, since the changes that do occur are usually very large.

Some doubts have been expressed as to the time at which q is actually recorded. In the apparatus that has been used in these experiments, an appreciable fraction of a second elapses from the time the adapting light is removed to the time the test patches become visible. It is probably true to say that the match is not made until $\frac{1}{2}$ sec. or 1 sec. has passed after the adapting light is removed. There is ample evidence (4, 5, 6), that rapid " off " effects occur when a stimulus is removed, and in the present experiments they will all be missed. These rapid reactions are apparently electrical in origin and are complete in so short a time that there is little reason to suppose that they play any part in the recovery process as we have measured it. It is, therefore, reasonably safe to assume that the factor q and the recovery curve record only those processes that are photo-chemical in origin.

Results

In all, 118 observers have been tested to date (June, 1938), 17 on the first model of the subjective photometer, 101 on the new model. The former served to demonstrate the value of further investigations, and as the tests were not made under such well controlled conditions as those made with the new apparatus, the results have not been included except when analysing the percentage distribution of different types of recovery curve. Eleven of the observers on the new instrument were known to be suffering from some visual disease and, with one exception, their results have also been omitted from the present report.

As indicated above, the observations are by no means easy and it was found that certain of the results, generally the recovery curves, were for some observers so poor that no use could be made of them. Accordingly some 10 per cent. of the curves have been discarded. About 25 per cent. of the curves were good, the agreement of the two observations on the same day being satisfactory and the mean curves for the two days also agreeing well.

The remainder of the observers gave curves in fair agreement and would no doubt have been better, if it had been possible to spend time in practice observations.

The Intra-ocular Factor, p.—The sensitivity of the right eye relative to the left eye is shown for 101 observers on a logarithmic scale in Fig. 4. The number of observers has been plotted who recorded a value of p within each 0·1 of the $\log_{10} p$ abscissa, and

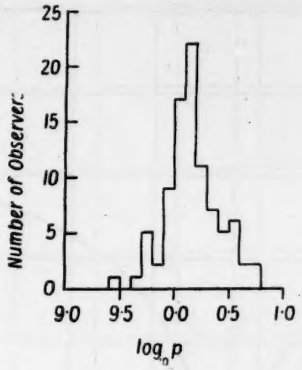


FIG. 4.

Distribution of measurements of intra-ocular factor, p. Number of observers occurring in each 0·1 of abscissa is plotted.

it is seen that the distribution has the general shape of a probability curve. The maximum occurs slightly to one side of the zero value, and while this might indicate a slight " right-eye " dominance of the observers, it is more probably due to an error in calculating the intra-ocular intensities, a binocular observation not easy to carry out with certainty.

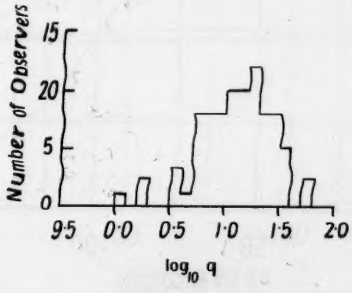


FIG. 5.

Distribution of measurements of adaptation factor, q. Number of observers occurring in each 0·1 of abscissa is plotted.

Taking the maximum of the curve as representing the true equality of sensitivity of the two eyes, it appears that for 20 of the observers one eye is more than twice as sensitive as the other and for two or three observers, one eye is more than four times as sensitive as the other.

The Adaptation Factor, q.—The values of q for 85 observers are shown in Fig. 5, in which the number of observers who

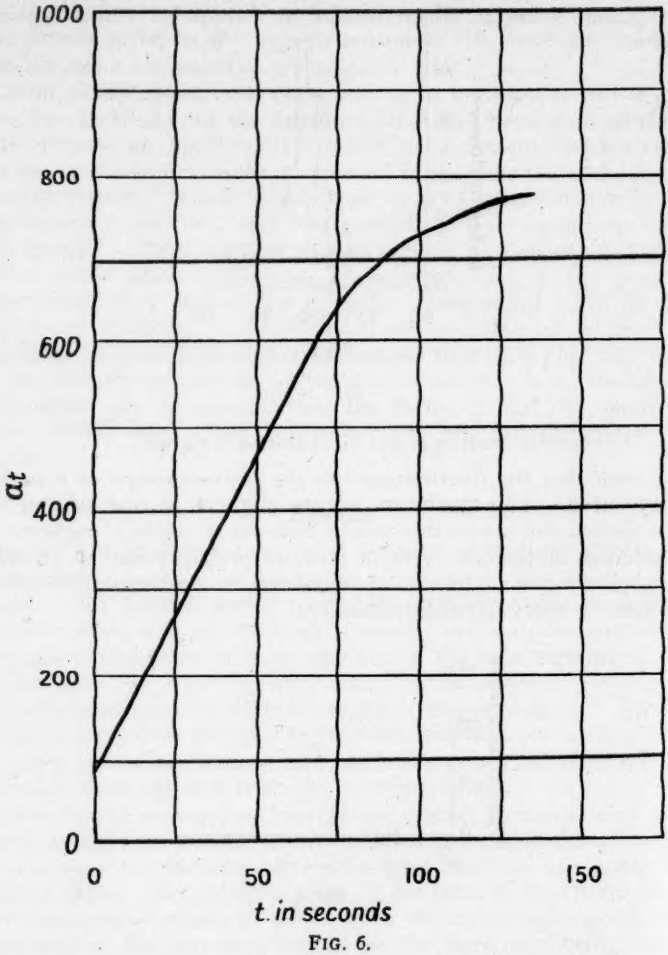


FIG. 6.

Recovery curve of direct type. Mean of 36 observers.

recorded a value of q in each 0·1 of the $\log_{10}$ q abscissa, is plotted. A very wide spread of the observations is apparent, with no well defined maximum occurring in the central block of the results. So far as any mean value of q has any significance, it may be taken as about $q=12{\cdot}5$ ($\log_{10} q=1{\cdot}1$). That, of course, holds only for the given adaptation intensity of 6,000 photons. For a

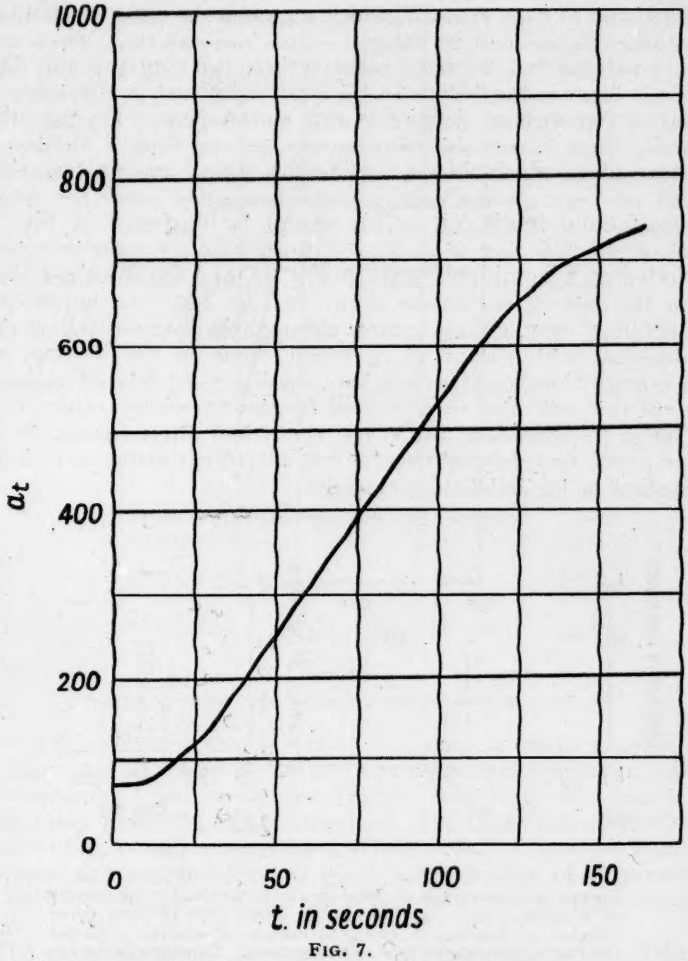


FIG. 7.

Recovery curve of delayed type. Mean of 26 observers.

few of the observers, it will be seen that log q is exceptionally small, an abnormality which is discussed later.

The Recovery Curve.—It has been found that there are two general types of recovery curve, those which show a recovery process that sets in as soon as the adaptation is removed (direct recovery), and those in which for some few seconds no recovery is apparent and in which some further small loss in sensitivity may even occur (delayed recovery). The two types of curve are illustrated in Figs. 6 and 7, which represent the mean of 36 direct recovery curves and 26 delayed curves respectively. There is a very well marked difference between these two diagrams and there is no doubt whatever that observers exist with a difference in recovery process as definite as that shown here. On the other hand, these curves are mean curves derived from a number of observations which show a considerable spread among themselves and the two groups each contain borderline cases for which classification is difficult. This spread is illustrated in Fig. 8, where the 36 values of a_{50} for the direct recovery cases have been plotted on a logarithmic scale in Fig. 8*a*, and the 26 values of a_{50} for the delayed curves are shown in Fig. 8*b*. An appreciable amount of overlapping occurs, although it does not follow that observers with values of a_{50} which occur in the overlap, are necessarily intermediate cases between direct and delayed recovery, since this will also be governed by the associated value of a_0. Out of 92 observers, 46 (50 per cent.) had direct curves, 32 (35 per cent.) had delayed curves, and 14 (15 per cent.) were intermediate or too indefinite to classify.

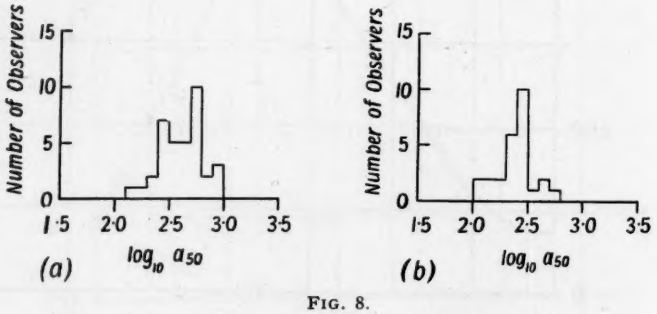


FIG. 8.

Spread of observations of recovery curve 50 seconds after removal of adapting light. (*a*) Log a_{50} for direct type recovery curve. Number of observers occurring in each 0·1 of abscissa is plotted. (*b*) Log a_{50} for delayed type recovery curve. Number of observers occurring in each 0·1 of abscissa is plotted.

Abnormal Recovery Curves.—Two abnormal results may be mentioned. In the first, it was found that those whose sensitivity was reduced to a relatively small extent by the light adaptation (q small) showed a rapid recovery curve. A typical case is illustrated in Fig. 9. It was, moreover, usually the case that these

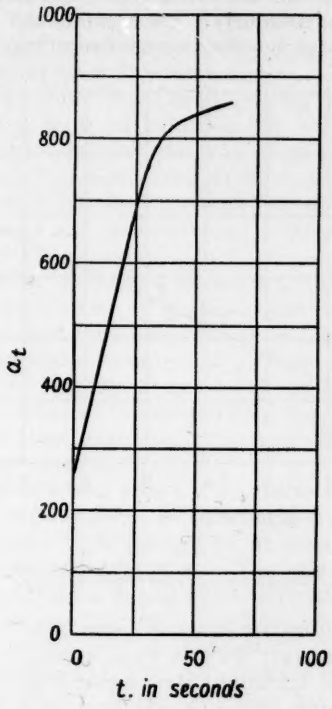


FIG. 9.

Recovery curve for observer having small adaptation factor.

observers were conscious of being unusually sensitive to glare; the same was also true of one or two observers for whom q was approximately 1 (no loss of sensitivity). The value of q was in these cases generally rather indefinite, but that such observers should exist, is very remarkable. The correlation between rapid recovery and susceptibility to glare needs further observations for confirmation, but it is of considerable interest and is discussed later.

The other abnormal case was that of a monochromat. This observer, a girl, had already been tested on a colorimeter to

confirm the monochromasy and to measure her luminosity curve. She also showed the other signs usually accompanying the defect, namely poor visual acuity and slight nystagmus. The adjustments of the subjective photometer presented some difficulties, but they were not insuperable. The greatest problem lay in actually obtaining the observations, since the observer was unable to see both patches simultaneously. A shutter was accordingly constructed and worked by the person operating the apparatus in

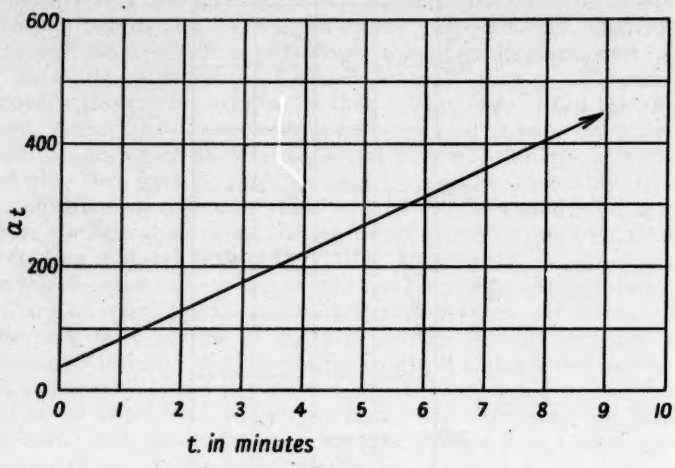


FIG. 10.

Recovery curve for monochromat.

such a manner that each patch was revealed in turn and the match was made by memory. In this way, a complete set of observations was possible, including the recovery curve, but the recording of the latter was only possible because it happened that the recovery was very slow and no appreciable change in sensitivity took place while the memory match was being made. The mean curve for three sets of observations taken on two different occasions is shown in Fig. 10. It is to be noted that the time scale is in minutes, so that the recovery is very much slower than the normal.

Discussion

The Intra-ocular Factor.—It is not, apparently, very abnormal for an observer to have one eye twice as sensitive as the other. A ratio of 4, on the other hand, is abnormally high and further examination of the person's vision would seem to be indicated.

Apart from its significance as suggestive of some more deep-seated trouble, a big difference in light sensitivity may in itself be responsible for other signs of visual defect, such as a reduced visual acuity due to the lower subjective brightness of the test chart, a discrepancy that might disappear if the illumination on the chart were raised for the eye concerned. Again, with one eye contributing to the brain only a fraction of the total visual response, a reduced stereoscopic acuity might also be expected.

Adaptation Factor and Recovery Curve.—The results for the adaptation factor show that even among apparently normal persons there is a wide variation in the extent to which light adaptation depresses the sensitivity. If pathological conditions are found to affect this factor, the changes produced will have to be very considerable for their existence to be demonstrated with certainty or to be of any practical use. This aspect can only be tested by further experiments.

Assuming that the correlation between a small value of q, rapid recovery and susceptibility to glare, is confirmed, the condition must presumably be due to the presence in the retina of an active photochemical substance having a high rate of regeneration. A balance between decomposition and regeneration would then occur at a high photochemical concentration, that would lead to an abnormally large visual response. Such an observer would therefore be peculiarly sensitive to light.

For those observers who adapt to a greater extent (large q) and have a direct, but slower, recovery curve, there should be less discomfort from high intensities, at least once the observer has become accustomed to the light. The balance between decomposition and regeneration would then occur only after the photochemical concentration had been considerably reduced, and the visual response would not be abnormally large. When first exposed to a high intensity, the concentration might be sufficiently high to cause a strong sense of glare, but this should soon disappear.

It is difficult to deduce anything about the photo-chemical condition of the observers with delayed recovery curves. From considerations of a balance point, the light sensitive substance should be almost completely decomposed before any balance would be reached with a process that apparently does not begin to recover for some seconds after the light source is removed. In that case a very high value of q would be expected, but in practice this is not found. It may be that the regeneration process is different when the light is acting from when the stimulus is removed or alternatively the total amount of light sensitive material in addition to its concentration may be the distinguishing feature. At the moment this can only be a matter for speculation.

No doubt variations in the metabolism of the retina from individual to individual will eventually have to be taken into account. Two instances may be quoted to illustrate this possibility: deficiency of vitamin A, which is known to affect visual purple regeneration (see *e.g.*, [7, 8]), and the effect of glucose on visual purple regeneration, as demonstrated by Therman.[9]

It would obviously be advantageous if the work on foveal adaptation could be linked up with measurements of the dark adaptation process. There is a good deal of activity at present in this field, especially in relation to pathological conditions of the eye,[7] and the results are complementary to those of the present paper. It would, for example, be very interesting to determine whether abnormalities in the rod mechanism are accompanied by similar abnormalities in the cone mechanism.

Acknowledgements

I should like to express my gratitude to the Medical Research Council for the special grant they provided for building the subjective photometer and to cover the expenses of the work, and also to the authorities at the Royal London Ophthalmic Hospital, Moorfields, for their help in providing facilities and accommodation to undertake the work. I have also to acknowledge my thanks to Mr. J. H. Nelson for assisting in the design of the apparatus and to Miss W. M. McKeon, who was responsible for recording the results of many of the observers. Lastly, I have to thank the observers themselves for assisting in such an essential manner in the investigation.

Summary

A new model of the subjective photometer is described, in which the effects of adapting the eye to a given intensity, are recorded by matching the test patch viewed in the light adapted right eye against a similar patch seen in the constantly dark adapted left eye. Observations on more than 100 observers have been recorded and are analysed. The data include the intra-ocular factor, that is, the sensitivity of the right eye relative to the left when both eyes are dark-adapted, the adaptation factor, which gives the factor by which the sensitivity of the eye is reduced for the given adaptation intensity (6,000 photons), and the recovery curve, which records the recovery of sensitivity after the adapting light has been removed. Among normal observers, two types of recovery curve have been found, a direct and a delayed recovery, in the latter of which no recovery is recorded for the first few seconds after the removal of the adapting light. The results are discussed in relation to the susceptibility of different observers to glare, to

the photo-chemical reaction in the retina and to the application of the method for pathological investigations.

REFERENCES

1. W. D. WRIGHT.—*Proc. Roy. Soc.*, B, Vol. CXV, p. 49, 1934.
2. ——— *Proc. Roy. Soc.*, B, Vol. CXXII, p. 220, 1937.
3. ——— and J. H. NELSON.—*Jl. Sci. Inst.*, Vol. XII, p. 373, 1935.
4. R. GRANIT and P. O. THERMAN.—*Jl. Physiol.*, Vol. LXXXIII, p. 359, 1935.
5. H. K. HARTLINE.—*Amer Jl. Physiol.*, Vol. CXXI, p. 400, 1938.
6. J. F. SCHOUTEN.—Visueele meting van Adaptatie. Utrecht, 1937.
7. J. B. FELDMAN.—*Arch. of Ophthal.*, Vol. XIX, p. 882, 1938.
8. G. WALD, H. JEGHERS and J ARMINIO.—*Amer. Jl. Physiol.*, Vol. CXXIII, p. 732, 1938.
9. P. O. THERMAN.—*Acta Soc. Sci. Fenn*, Helsingfors, Ser. B, 2, No. 1, 1938.

ANNOTATIONS

Sulphanilamide in the Treatment of Trachoma

In the *Lancet* of October 29, 1938, appeared an article by three members of the Sudan Medical Service on this subject. Kirk, McKelvie and Hussein have tried prontosil album, given in tablet form by the mouth, in weekly courses with a week's interval between each course. The dose of each tablet, 7½ gr. thrice daily (proportionately reduced for children), was selected arbitrarily.

The paper is based on the results in 25 cases of adults. A convenient table allows the main facts to be seen at a glance. The results appear to be encouraging, especially as regards the corneal complications of pannus and keratitis. The treatment is simple and less painful than the local treatment of the disease, but it is, of course, too early to say whether the results will be permanent. It may be noted that cases of trachoma complicated by spring catarrh did not do so well as uncomplicated cases.

Ophthalmologists throughout the world will be anxious for further first-hand reports on the use of this drug in cases of trachoma.

Volume XXIII

With the completion of our 22nd volume this Journal may fairly be said to have passed out of the stage of adolescence. Recently the amount of original material in hand has been greater than usual and the Editorial Committee has considered the question of increasing the size of the monthly numbers. When the project of a *British Journal of Ophthalmology* was first being discussed in 1916 the hope was expressed that it would be possible to issue a 64 page number every month and even a larger number of pages if thought

desirable. Up till now it has not been thought advisable to increase the size and in the past it has not always been possible to issue a 64 page number every month. Last year this was done and it is now proposed to issue an 80 page number occasionally. As we have already said the number of original papers in hand seems to warrant this extravagance; and with the first issue of the new year we offer an 80 page number for the first time.

ABSTRACTS

I.—THERAPEUTICS AND OPERATIONS

(1) **Moretti (Catania).—Mules's operation. (Inclusioni d'olive di vetro nel guscio sclerale).** *Ann. di Ottal.*, October, 1936.

(1) **Moretti** has adopted Poulard's form of artificial vitreous; Mules used spherical masses which were ill-adapted to the sclera after the cornea had been removed and were not infrequently extruded; Poulard has had ellipsoids made with long axis 15 or 17 mm., and the short axis 9 or 11 mm. These fit into the cavity left after removal of the cornea and adjacent sclera, as advised by Mules, and are more easily retained. Poulard at one time kept the cornea intact and found the resulting cavity so large that the stump was unsuitable for Snellen's eyes, and gave it up.

The author has operated in this way for some two years and has had about 75 per cent. successes. He thinks the risk of sympathetic has been greatly exaggerated; he is inclined to think that most, if not all, of the cases recorded were not really sympathetic ophthalmitis. The operation is, in his opinion, to be preferred to either enucleation or evisceration; even in panophthalmitis he has used it successfully, and advises its performance at the earliest possible moment.

HAROLD GRIMSDALE.

(2) **Bencini (Siena).—Iridencleisis in chronic glaucoma. (Iridencleisis di Holth e glaucoma cronico).** *Boll. d'Ocul.*, June, 1938.

(2) The selection of operation in cases of chronic glaucoma is always difficult, and no constant rule can be laid down. The operations most generally selected are those giving a leaking scar, the sclerecto-iridectomy of Lagrange, and trephining of Elliot. The former **Bencini** dislikes, on account of the large opening in the sclero-cornea. (He does not seem to have tried the more recent forms of Lagrange in which the external wound is much smaller.)

The other method of attack is cyclodialysis, which aims at opening the way from the anterior chamber to the suprachoroidal space. Holth, by leaving a small piece of iris in the wound unreduced, is able to make a scar which allows filtration. His method is to incise the sclera about 1 mm. from the limbus, to draw out a fold of iris and to incise this fold radially; if too much iris protudes, to cut the excess off. When the patient is very nervous, the author has adopted this operation in preference to trephining and has found it successful.

HAROLD GRIMSDALE.

BOOK NOTICES

The Aetiology of Trachoma. By LOUIS A. JULIANELLE, Ph.D. Pp. 248, 10 plates. The Commonwealth Fund, New York, and Oxford University Press. Price, 14s.

During the last six years JULIANELLE has carried out a vast amount of experimental work on the aetiology of trachoma, accounts of which have been published. He has collected these and now presents the first monograph on the aetiology of the disease to be published since that of our regretted friend and colleague, Axenfeld, in 1914.

The mass-infection of some of the continents of the world with trachoma is now beginning to be recognised, but it is insufficiently known that the disease occasionally appears in wealthy families even in England, and when it is impossible to trace its origin.

The subject is therefore of great importance, which in conjunction with the value of Julianelle's book, merits a thorough study of the latter.

Experimental transmission to animals.—In 1905 Morax transferred trachoma from man to one of nine chimpanzees, though he did not publish this until 1911. Hess and Römer reported in 1906 that they had been able to infect two baboons. These experiments have been repeated by others with orang-utan, gibbon, cercopithecus, grivet, guenon, vervet, semnopithecus; macacus, varieties of innus, rhesus, cynomolgus, sinicus and mordax; and the New World monkey, cebus capucinus.

Transmission of trachoma to animals other than monkeys and apes has never been effected.

Trachoma in monkeys and apes lacks the two differential features of human trachoma which are corneal involvement and conjunctival scarring. Within a few days of the inoculation of infectious material, which is done by rubbing, pricking or injection of the conjunctiva, there is slight inflammation and hyperaemia. After a period of a few days to a month follicles appear near the inner canthus and then at the outer canthus, and form

a ridge covering the upper retrotarsal conjunctiva. Later the follicles extend to the conjunctiva of the superior fornix, of the tarsus, and of the lower lid, and sometimes even to the bulbar conjunctiva.

Papillary hypertrophy as seen in human trachoma Stage 11b is never seen. Eventually the animals recover spontaneously without any sign of the past infection. When one eye only is inoculated the disease usually spreads to the other eye.

In order to show that the experimental disease really was trachoma, inoculations of human folliculosis were made into suitable monkeys with negative results; many of these monkeys were subsequently inoculated with human trachomatous material and developed a follicular conjunctivitis, which is believed to have been the simian equivalent of human trachoma.

In the higher types of monkey inoculated Halberstaedter-Prowaczek Körperchen (H. P. K.) were found, but never in the lower types, such as macacus rhesus.

A considerable variation in infectivity among different trachomatous patients was found, for in spite of careful selection to include only those in early and active stages of the disease, only half were capable of transmitting trachoma to animals.

The monkeys themselves vary greatly in their susceptibility to the experimental disease; their age seemed not to be a factor.

Successful transmission of the experimental disease from an infected to a normal animal was effected, but less frequently than was observed in inoculations with human tissues. In these cases there was a longer incubation, and a milder disease of less prolonged duration.

There is no immunity set up; immediately after the conjunctiva returned to normal, it was possible to reinfect some animals several times. Experimentation with the bacterial flora of the conjunctiva, as was to be expected, was always negative.

Rickettsiae.—Rickettsia is the name given to certain small bacteria-like bodies which are found in the alimentary canal of insects and other arthropods, and are frequently associated with disease in man and animals.

The first named species was described by Rocha-Lima in 1916, who found these bodies in lice taken from patients with typhus fever; he proposed the name *Rickettsia Prowaczekii* in honour of Ricketts and of Prowaczek, both of whom died of typhus fever while investigating the disease. Other pathogenic species of Rickettsiae are known, one of which is *R. wolhynica* or quintana or pediculi, causative of trench fever. Many non-pathogenic species have been described. Infection of insects occurs either by blood-sucking or by feeding on infected excreta.

Rickettsiae are of minute size, 0·25 to 0·3 μ in diameter; they are irregular in shape, round, oval, diplococcal, and dumb-bell shaped; they occur in very large numbers, or even masses; they have a well-stained appearance and reddish-purple colour with Giemsa. They cannot be cultivated apart from living cells; growth in tissue-culture is difficult.

The resistance of Rickettsiae has not been fully studied. The Trench fever Committee found that the infectivity of louse excreta was destroyed by exposure

to moist heat at 60° for 20 minutes, and to dry heat at 100° for the same time.

In typhus fever and trench fever man is the reservoir of the virus; for the other viruses it is the biting insect which is the reservoir in human rickettsioses, and in the animal rickettsioses animals of the same species.

The immunity which apparently follows some of the rickettsioses is due to a latent infection, the individual or animal remaining as a reservoir of the virus. (Parrot, Arch. Instit. Past. d'Algerie, XV, 1937, Nos. 2 and 3.)

As Julianelle points out Rickettsial diseases have a sudden onset and run an acute course; they are always followed by a definite and permanent immunity; they are cultivable in tissue-cultures; they stimulate and react with specific anti-bodies, and they possess a broad tissue activity. He considers that neither trachoma nor its infective agent fulfils these conditions.

The inclusion body of trachoma.—Granular inclusions in epithelial cells, which are now known to be characteristic of virus diseases, were first discovered by Halberstaedter and Prowaczek.

They were on an expedition to Java for the purpose of studying the results of the inoculation of orang-utans with syphilis. It occurred to them to inoculate the conjunctiva of these animals with trachoma, with the result that they discovered curious changes in scraping from this membrane. On examination of the human conjunctiva from which these scrapings were made, similar results appeared. These were collections of granules or corpuscles included within epithelial cells and were called inclusion bodies, or Halberstaedter-Prowaczek Körperchen, often abbreviated to H.P.K. They concluded that these were the active agent of the disease, which they characterized as an epitheliosis.

They may be demonstrated as follows: the upper lid is everted and lightly scraped with a sterile platinum spatula or with the belly of a scalpel, after first wiping away any mucus or discharge with a surgical swab; the epithelial cells thus obtained are spread as a film on a specially prepared glass slide. Coles thus describes their preparation: the slides are first rubbed thoroughly on both sides with whiting (wet chalk); this is washed away under the tap; the slides are then rubbed with the cut surface of a potato, and then polished with a clean linen handkerchief, after which they are stored in absolute alcohol; this is dried off with a handkerchief before use.

The films are then fixed in methyl alcohol for 15 minutes, and stained in a mixture of 10 drops of Giemsa and 10 c.c. of distilled water for 24 hours, washed in distilled water and examined. Julianelle recommends as being more expeditious the use of Wright's stain; a few drops of the stain are placed on the film and diluted threefold with distilled water, which is allowed to remain for 5 minutes, after which it is washed with distilled water and examined.

In positive preparations there are seen red-staining granules (elementary bodies) and larger blue-staining bodies (initial bodies), so named by Lindner. Both of these varieties are found within an epithelial cell, often capping it; they may, on occasion be found free and not ingested by any cell.

The discovery of epithelial cell inclusion (H.P.K.*) in some other conjunctival inflammations caused at first some confusion to ophthalmologists. These were non-gonococcal ophthalmia neonatorum, inflammation in the genital tract of the mothers of infants infected with non-gonococcal ophthalmia, swimming-bath conjunctivitis, and epitheliosis conjunctivae (Samoa, which is probably identical with trachoma).

They may be found in all stages of trachoma, except in the cicatrized stage, Tr. IV, if a sufficient number of preparations are made from different areas of the conjunctiva, and if the microscopist exhibits sufficient zeal in his search for them. They are found with difficulty or not at all in the conjunctiva of animals which have been experimentally infected.

Julianelle states that, in his opinion, it has not been possible to demonstrate the living nature of H.P.K. by means of propagation. They may be a product of cellular reaction to ingested cells, bacteria or harmless parasites. Animal experiments on the filtrate obtained by passing infective material through Berkefeld or Elford filters show that the filtrate is irregularly infective.

The evidence indicates that trachomatous material may be liberated from extraneous bacteria by passage through the testicular tissue of rabbits. The absence of any tissue reaction in the rabbit, the inability of the infective agent to survive serial passage, and the maintenance of infectivity in many instances at a given level, all suggest that the infective agent does not propagate in the testicle but is merely preserved and freed from cultivable bacteria.

Julianelle has failed to cultivate the infective agent of trachoma by tissue-culture. By this method, however, Poleff states that he has been successful, although there has been as yet no proof of infectivity of the tissue-cultures for monkeys.

Julianelle has found that blood from patients with trachoma contains no demonstrable substance capable of inactivating or neutralising the infective agent, as measured by the development of experimental trachoma in monkeys.

In his final discussion the author mentions that a recent development in the studies on the aetiology of trachoma portrays the causative agent as due to Rickettsiae. This is from Cuénod's laboratory where it was found that inoculations of ground lice containing Rickettsiae derived from trachoma may induce specific infection in monkeys, and even in man. Whether the Rickettsiae

* It has now been recognised by general bacteriologists that H.P.K. are found in all virus diseases. (Reviewer).

in the lice actually cause the infection or some other agent simultaneously present, has not been revealed.

Julianelle has shown that by testicular passage, the infective agent has been observed in an active condition. In the absence of any cultivable or microscopically visible forms, such testicular tissues were capable of inducing infection in monkeys. Since no demonstrable multiplication of the infective agent was evident, it may be assumed that the infective agent survived passage, and became attached to or absorbed by the testicular tissue. Thus it may be that the infective agent is likewise adsorbed to the louse tissue which may or may not be secondarily infected with possible extraneous (that is non-trachomatous) Rickettsiae.

Thygeson and his co-workers obtained a bacteriologically sterile filtrate of human trachoma through a collodion membrane of 0·6μ A.P.D., which filtrate contained what were considered to be elementary bodies. Upon inoculation in a human volunteer typical trachoma was induced, and within five days following the inoculation inclusions and elementary bodies began to appear and remained over a long period. The authors consequently concluded that the elementary body is the infective agent of trachoma.

It appears that the infective agent is characterised by an exquisite tissue specialisation. Completely unable to cause clinical infection in lower animals, it induces in monkeys and apes a conjunctivitis of a low order, healing as it does spontaneously without affecting the cornea or initiating cicatrisation. In man the infection is sharply circumscribed in the conjunctiva and its adnexa. It should not be surprising, therefore, if it fails to grow in cultures of avian or mammalian tissues.

At the present time we may take it that the elementary body is the active principle of the virus, as it is in such a disease as psittacosis. Whether the elementary body belongs to the Rickettsiae or not requires for the scientific mind of Julianelle more certain demonstration. From examination of microscopical specimens provided by Busacca and by Cuénod he is unable to recognise their so-called Rickettsiae as other than detritus.

The conclusions arrived at by Foley and Parrot, working at the Pasteur Institute of Algeria differ from those of Julianelle. They consider that the elementary bodies of Halberstaedter and Prowaczek are living organisms and belong to the genus Rickettsiae; that the Rickettsiae trachomae of Busacca are elementary bodies; that the elements described by Cuénod and Nataf consist of detritus; and that the Rickettsia trachomatis is transmitted by direct contact, as in non-gonococcal ophthalmia neonatorum and swimming-bath conjunctivitis, without the intervention of an arthropod host.

Augenärztliche Eingriffe. By Professor MELLER. Fourth Edition. Pp. 416, 248 illustrations. Vienna: Springer. Price, R.M. 37·80.

The 4th edition contains a number of new illustrations and descriptions of operations, particularly dacryocystorhinostomy, certain plastic repairs; a new technique for reconstruction of a contracted socket; iridencleisis and retinal detachment.

Contributions have been made by Böck, Kofler, Pillat and Sallman. Böck and Sallman have written on retinal detachment and described the investigation and a number of surgical procedures for the treatment of this disorder.

The endonasal technique for dacryocystorhinostomy is elaborated at some length and profusely illustrated, two pages being devoted to the instruments used in this operation. There is an interesting account of iridencleisis and its value as a surgical procedure in the treatment of chronic glaucoma.

In the chapters on plastic repair of the lids the principles of Imre's tongue-shaped sliding pedicle from the adjacent skin is admirably described and illustrated.

The transportation of thin tongue-shaped flaps in the treatment of trichiasis affecting a limited area of the lid margin is not advocated by all plastic surgeons for the transposed skin from the upper lid contains fine hairs which may cause a continuation of corneal and conjunctival irritation. Some form of mucous membrane inlay is thought to be more satisfactory in cases where this operation is necessary.

It is disappointing to find that the engravings of the cataract extraction operation shown in previous editions of this work are retained in the 4th Edition. These illustrations show retraction of the lids by the assistant's thumb and fingers, a procedure which is scarcely necessary when there are available to-day retractors which are constructed to rest on the bridge of the nose and temporal region, on the frontal region and not to press on the globe. If a retractor is not favoured by the operator, satisfactory separation of the lids may be effected by a suture passed through the skin and clamped to the sterile towels with forceps. Although the majority of the illustrations are admirable some do not illustrate accurately the details of an operation.

The printing and production are good.

The Perception of Light. By W. D. WRIGHT, D.Sc., A.R.C.S. Lecturer on Physics, Imperial College of Science and Technology. Pp. 100. London and Glasgow: Blackie & Sons. 1938. Price, 6/- net.

During the past few years profoundly important and fruitful research has been accomplished in the domain of the physiology of vision. The most important researches have been carried out under the aegis of the Physiology of Vision Committee of the

Medical Research Council and of the Illumination Committee of the Department for Scientific and Industrial Research. In most of these researches both bodies have co-operated with great advantage to each, for the problems involve knowledge both of physics and physiology. The chief workers on the more particularly physiological side have been Lythgoe, and his co-workers, Tansley and Goodeve, and Mrs. Campbell and Mrs. Bourne; those on the physical side have been Stiles and his co-worker Crawford, and Wright.

In this excellent little book, Dr. W. D. Wright has gathered together most of these researches and set them out in relationship to previous knowledge of visual sensations. In addition, he has correlated many of the results with the work of Granit and his associates on the electroretinogram, and with work by Weston and others on factory lighting. The chapters deal with a general account of visual phenomena, vision at low and high intensities, glare, visual sensations, and some recent researches. It is the clearly expressed summaries of the recent work which make the book so valuable, and indeed indispensable to those interested in the physiology of vision. It is well printed and illustrated with diagrams, and contains a useful bibliography.

Spectral-Transmissive Properties and Use of Coloured Eye-Protective Glasses. By W. W. COBLENTZ and R. STAIR. Pp. 28. U.S. Department of Commerce, Government Printing Office, Washington. (National Bureau of Standards, C421). 1938.

Various types of tinted glasses have long been used for the protection of the eyes under trying conditions of illumination. It is unfortunately true that they have been as often abused, frequently through ignorance of their properties and regrettably, too, from sheer quackery. The present brochure acts as a powerful cathartic. The spectral transmission of a large number of tinted glasses has been estimated and illustrated by absorption curves. There can be little doubt as to the accuracy of the work since it emanates from the U.S. Bureau of Standards, and was carried out by Coblentz, whose work is thoroughly reliable.

Triennial Report and Statistics of the Government Ophthalmic Hospital, Madras, 1935-1937. 1938. Price, 6 annas.

The report follows the usual annual precedent of past years and contains in tabular form the numbers of admissions to in- and out-patient services, the numbers of operations performed, together with details of training of medical students, post-graduate work and finance. Lt.-Col. P. Verdon, I.M.S., has succeeded Col. R. E. Wright, C.I.E., as Superintendent. We hope that his period in charge will be a happy one and feel sure that the hospital under his administration will maintain its great reputation.

Galileo and the Freedom of Thought. By F. SHERWOOD TAYLOR, Ph.D., M.A., B.Sc. Pp. 212. London: Watts & Co. 1938. Price, 7/6.

In this book the author has told the story of Galileo and his discoveries, and his place in the history of scientific thought. He has given a good description of dark ages dominated by the superstitions of the church and the Aristotelian philosophy. The struggle between Galileo and the Church is well elucidated, and even if Galileo never said " Eppur si muove," one feels that the slogan accurately reflects his real thoughts. Galileo's observations and experiments are well described and illustrated, and the book is enriched with several portraits and plates.

OBITUARY

JOHN MARTIN WHEELER

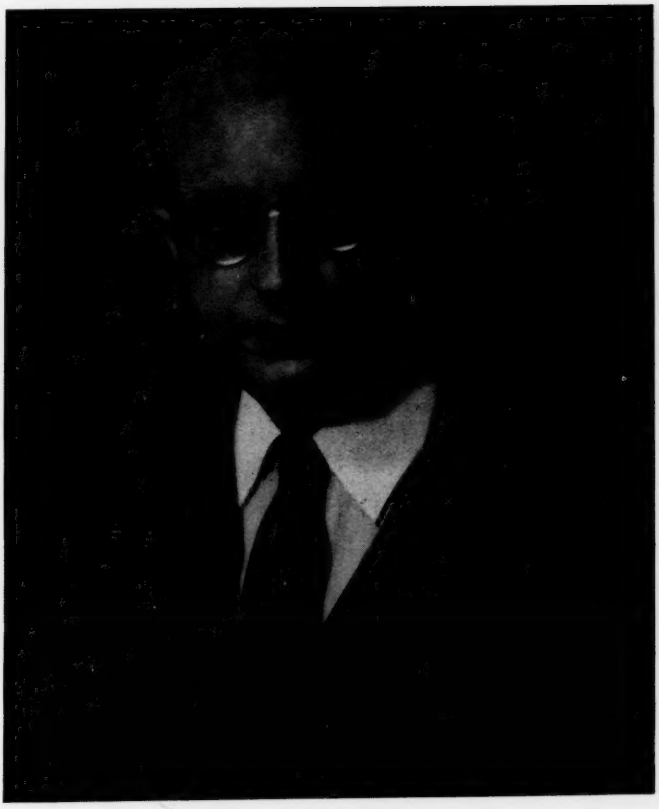
John Martin Wheeler was born on November 10, 1879. His family originally came to America from Cranefield, Bedfordshire. He received his early education in the public schools of Burlington and the University of Vermont from which he graduated in arts in 1902 and in medicine in 1905. In 1906 he received the B.Sc. degree and during the years 1906 and 1907 he was an instructor in anatomy. In 1908 John Wheeler became an intern in the New York Eye and Ear Infirmary. His natural ability and hard work soon gained him a prominent place among ophthalmologists. He served on the Councils of the American Ophthalmological Society and the American Academy of Ophthalmology and Oto-laryngology, and in 1933 he became President of the latter.

Wheeler was appointed Professor of Ophthalmology at Columbia University in 1928 and three years later he became Director of the newly-built eye institute at the Columbia-Presbyterian Medical Centre.

His special interest lay in surgery, particularly plastic surgery around the eyes, a field in which he felt that ophthalmic surgeons did not do nearly so much as they should.

Three years before his death he lost one eye but so great was his surgical skill that after a brief period of practice he was able to operate as efficiently as before this adversity fell upon him.

In 1928 the University of Vermont conferred upon him an honorary degree of D.Sc., and in 1933 he received a similar award from Middlebury College. In 1931 the decoration of Commander of the Order of the Cross of Siam was conferred upon Wheeler after he had operated on the King of Siam's eyes, and in the same year he was awarded the Leslie Dana Medal for distinguished service in the conservation of sight.



JOHN MARTIN WHEELER

His widow and four children survive him. Wheeler's death is a great loss to ophthalmology.

We are indebted to Mr. Basil Graves for the following appreciation :—

It is difficult for one who knew John Wheeler and his family well to do justice to his memory in the compass of a few words.

Dr. Wheeler, though a disciplinarian, was a craftsman and an artist who had in full measure that spirit which, seeking neither prestige nor shelter in scholastic obscurity and unfettered by the claims of any inflexible synoptic formalism, welcomes every opportunity of enquiry into change; and which, in the desire to record and explain change, creates problems in the very act of seeking them.

Dr. Wheeler's associates and students always speak of his unselfish interest in their progress. It is said that his chief interest lay in the development of young men and in the perfection of their operative technique. He was a man of quiet courage and masterly skill. In the surgery of the eye "he had no peer." He had a remarkably intuitive respect for the vitality of living tissue and a healthily sceptical attitude towards any disparagement of "the things of sense." He was never resentful of the accomplishments of others and a colleague has stated that he knew none who was ever jealous of his. He would always refrain from publishing anything until he felt sure that it would probably endure. Several instances could be quoted to illustrate how he preferred to demonstrate his original ideas to his friends and visitors at his clinic, permitting them the opportunity of using the ideas and even of publishing the work if they so chose. He was acutely critical of his own work but generously forgot any mishaps or mistakes of his associates. The *American Journal of Ophthalmology* (October, 1938) writes:—"It was his way to ask opinions of whomever he was with. He was a good listener. Quite free from the habit of interrupting, he would, in fact, often wait a noticeable time after the speaker had finished before replying. His own suggestions were usually made with a twinkle in his eyes—a very characteristic feature which was never far away and which was one of his most lovable attributes, for he was endowed with a delightful sense of humour." This encouragement and tolerance of the suggestions of others, particularly those of juniors, resembled the attitude of the late Mr. Treacher Collins towards constructive thought. Wheeler, who first met Collins when on a visit to England about fifteen years ago, never ceased to express his admiration for the whole of Collins' work and outlook. He published some fifty original communications and, as was the case with the work of Treacher Collins, they were characterised by the absence of dependence upon the bibliographical compilations of the work of others. Disappointment has been

expressed that Wheeler did not write a text-book on plastic surgery of the eye. It is a matter of no surprise that he did not and the reason is probably amply provided in any historical consideration of the psychology of the craftsman and of the socially, if not biologically, inevitable demarcation between the mode of thought of the craftsman and that of the academician; his approach to problems recalled the initiative of those of the now well-known scientists of the XIX century who achieved what they did largely because they began as independent amateurs in their chosen subjects.

Owing to the social organisation of his unique achievements, as much as to the manner in which he himself pursued his life's work, the passing away of John Wheeler, at the age of fifty-eight when he was in full professional activity, will fortunately not mean that the world will be deprived of work of rare value through the loss of one whose heart—to quote words written in his own country—was the very heart of ophthalmology. He has left, in the institution in New York of which he was the Director, a legacy of tradition and achievement which, owing to his foresight and kindness, will be perpetuated by the surviving group of men who, in helping him, derived so much from the example of his sustained and generous help.

NOTES

Deaths

THE death of Professor William McDougall deprives psychology of a forceful and distinguished exponent. He is best known for his epoch-making book on the Instincts contained in his "Introduction to Social Psychology," and for his many works on social and abnormal psychology advocating his hormic theory. But it may be doubted whether these works represented his greatest claims to honour as a scientist. These were probably his highly original experimental studies on colour vision (published—and buried— in "Mind," a journal of limited circulation), on after-images, and above all on recurrent vision (published in the *British Journal of Psychology*). All this work was done during his tenure of posts at University College, London, and at Oxford, before his migration to the United States, as the successor of Professor Münsterberg at Harvard. Mention should also be made of his studies on cutaneous sensibility in primitive races as a member of the Cambridge Anthropological Expedition to the Torres Straits in 1898. In his experimental and anthropological work he was a worthy disciple of his Cambridge teacher, Dr. W. H. R. Rivers.

Ralph Kanthack, the elder brother of the late Dr. A. A. Kanthack, the distinguished Professor of Pathology, died on November 12,

1938. Mr. Ralph Kanthack was a well-known physicist and an authority on optics. He was the author of several technical works, among them the Lehrbuch der Geometrik.

* * * *

Ophthalmic Surgery in Hungary

AN address on "The surgery of the eye in Hungary" will be given by Professor Emile de Grósz, of Budapest, in the Tennent Memorial Institute, Church Street, Glasgow, on Wednesday, January 18, 1939, at 8.15 p.m.

* * * *

Appointment

ARTHUR LISTER, M.B.(Camb.), F.R.C.S., has been elected Assistant Ophthalmic Surgeon to the London Hospital.

* * * *

National Society for the Prevention of Blindness, Inc.

DR. J. WARREN BELL has been appointed Medical Director of the National Society for the Prevention of Blindness. He has had great experience as Director of Maternal and Child Health in Nebraska State as well as in New York State.

FUTURE ARRANGEMENTS

1939

January 13.—Section of Ophthalmology, Royal Society of Medicine.

January 20.—North of England Ophthalmological Society, Annual Lecture, at Manchester.

January 21.—North of England Ophthalmological Society, Annual Lecture, at Manchester.

February 3.—North of England Ophthalmological Society, at Newcastle-upon-Tyne.

February 3.—Midland Ophthalmological Society, at Oxford Eye Hospital.

February 10.—Section of Ophthalmology, Royal Society of Medicine.

March 3.—North of England Ophthalmological Society, at Liverpool.

March 10.—Section of Ophthalmology, Royal Society of Medicine. (Clinical Meeting.)

March 31.—North of England Ophthalmological Society, at Sheffield. (Joint Meeting with the Midland Ophthalmological Society.)

April 20-22.—Ophthalmological Society of the United Kingdom, Annual Congress, at the Royal Society of Medicine.

May 19.—Midland Ophthalmological Society, at Gloucester Royal Infirmary and Eye Institution.

June 9.—Section of Ophthalmology, Royal Society of Medicine. (Annual.)

July 6-8.—Oxford Ophthalmological Congress, at Oxford.

October 6.—Midland Opthalmological Society, at Birmingham and Midland Eye Hospital. (Annual.)

CONTEMPORARY OPHTHALMIC LITERATURE

American Journal of Ophthalmology. *November, 1938.*

BRALEY. Inclusion blennorrhea. A study of the pathological changes in the conjunctiva and cervix.
SMELSER. Treatment of experimentally produced exophthalmos with thyroxin and other iodine compounds.
BIELSCHOWSKY. Lectures on motor anomalies. 3. The signs and symptoms of heterophoria.
JULIANELLE, HARRISON and LANGE. Studies on inclusion blennorrhea. 3. Experimental considerations of the aetiology.
SAMUELS. The histopathology of papilledema.
LEBENSOHN. Value of muscle-balance tests in routine refraction.

Archiv. für Ophthalmologie. *November, 1938.*

SALZMANN. Glaucomatous corneal degeneration.
SCHMELZER. Researches on the common causes of glaucoma.
KARBOWSKI. The pathology of coloured vision.
MATSUDA. The harmful effect of hepato and lieno-toxin on the eyes.
SEIDEL. The physiology of accommodation in human eyes.
SEIDEL. A very rare retinal disease as a local phenomenon of a general disease with a hereditary basis.
WINCKLER. Contribution to the genesis of dermatogenous cataract.
MIKLOS. Does tenotomy give a fleeting squint?
WIEDERKEHR. Further contributions to the clinical and histological aspects of senile anterior capsule desquamation.
HOSHI. Ocular disease associated with morbid morphological blood formation in rabbits.
SUGITA. Further researches on the nature of spontaneous retinal detachment, especially on the physico-chemical origin.

Archivio di Ottalmologia. *July-August, 1938.*

CAVALLACCI. The pathogenesis of blepharochalasis.
CORDERO. The action of α-dinitrophenol on the eyes.

Rassegna Italiana d'Ottalmologia. *July-August, 1938.*

SGROSSO. The probable diagnosis of ocular metastatic carcinoma.
RAVERDINO. Turbinotomy for dacryocystorhinostomy "ab externo."
CIOTOLA. Two cases of double rosette cataract (anterior and posterior) following trachoma.
TREMATORE. Parenchymatous keratitis in acquired syphilis.
ANGIUS. Lymphangioma of the limbus.
MATHIS. Ocular lesions in myxomatosis of rabbits.
AGNELLO. Papilloma of the caruncle.

Archivos de Oftalmologia de Buenos Aires. *August, 1938.*

SCHMELZER. The general causes of the origin of primary glaucoma.
ADROGUE. Disturbances of associated ocular movements.
MALBRAN. Traumatic lesions of the iris. Partial disappearance of the iris; total disappearance (irideremia).
ALLENDE. Pterygium. Seventy-one operations for this disorder.

Klinika Oczna.

MAJEWSKI. Presbyopia and exophoria.
HRYNKIEWICZ. Sympathetic ophthalmitis.
MADROSZKIEWICZ and PRZYBYLKIEWICZ. Tuberculosis of the conjunctiva and Parinaud's conjunctivitis.
GRAFOWA. The problem of detachment of the hyaloid membrane.
ZAMENHOF. A small projector for campimetry.
MUSIATOWA. The problem of blindness in Poland.
KAPUSCINSKI. Bacteriology of trachoma.